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ABSTRACT

This report summarizes the characteristics of physics education in 12 countries: Argentina; Brazil; Canada; Chile; Colombia; Costa Rica; Ecuador; Guatemala; Jamaica; Mexico; the United States; and Venezuela. An introductory chapter describes the goals of the Council on Inter-American Conferences on Physics Education, historical background, audience, and organization of the report. The next 12 chapters include: (1) general information about the country; (2) description of the educational system; (3) data and information on the state of physics education at each of the educational levels (primary, secondary, and tertiary); (4) descriptions of graduate programs in physics; (5) efforts to improve physics education in the country under consideration; and (6) an analysis on the professional physicist. The final cross-country examination chapter includes a summary of the data and information collected. A general bibliography and bibliographies by country are appended. (YP)

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Physics Education in the Western Hemisphere: A Report from Twelve Countries

Andres F. Rodriguez
Editor-in-Chief

Published by American Association of Physics Teachers

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Foreword

The present report was prepared under the auspices of the American Association of Physics Teachers as a part of its contribution to an international cooperative effort symbolized by the 1987 Inter-American Conference on Physics Education. In making the report available to a larger readership, the Association hopes that its publication will help to create a wider understanding of the conditions, opportunities, accomplishments, and difficulties of physics education in the Western Hemisphere.

Among the many who have contributed to the preparation of this volume, one stands out as especially deserving of commendation--the Editor-in-Chief. Andres F. Rodriguez, Professor of Physics at the University of the Pacific, took on the task of reducing the twelve separate "country reports," understandably somewhat different in format and approach, to a coherent whole. Fluent in Spanish and English and acquainted with teachers, students, and educational systems through personal experiences in several Western Hemisphere countries, Professor Rodriguez was ideally qualified for his editorial duties. He has made a major contribution in this report to our understanding of the common features of the national systems of physics education among the countries of the Americas, as well as their unique national characteristics.

William C. Kelly
American Association of Physics Teachers

Andres F. Rodriguez

Professor, Physics Department, University of the Pacific. Doctor in Sciences received 1955, Havana University, Cuba. Post Doctoral work done: Institute of Physics, Bariloche, Argentina, 1960; Institute of Physics, UNAM, Mexico, 1961-63; ORAU, Oak Ridge, Tenn., 1965-66. Taught at Havana University, National University of Mexico, (UNAM), Mexico; University of Puerto Rico, (Humacao); University of the Pacific, since 1964. Consultant for AEC, Latin American International Program. UNESCO Expert, 1971-73, Colombia, South America. Senior Fulbright Lecturer, summers, 1973-74. Recipient of the Alex and Fay Spanos Distinguished Teaching Award (University of the Pacific), 1979. Recipient of the Distinguished Faculty Award (University of the Pacific), 1987. Received Fellowships from OAS and NSF International Program. Selected as Outstanding Educator (Outstanding Educators of America), 1974. Member of the American Physical Society, American Association of Physics Teachers, and American Society for Engineering Education. Author of several books and articles.

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Physics Education in the Western Hemisphere: An Introduction

Preamble

"The Inter-American Conference on Physics Education" that was held in Oaxtepec, Mexico, during July 20-24, 1987, provided the stimulus for the preparation of this report on the state of physics education in the Western Hemisphere circa 1987.

Prior to this conference, the Council on Inter-American Conferences on Physics Education invited physics-educator colleagues throughout the Americas to serve as "country reporters" on the state of physics education in their countries.

The Council suggested an outline for the preparation of the reports, and the country reporters tried to complete their tasks according to these suggestions. But, of course, they were not able to fill in the outline completely because data were not often available and the time required for completing the reports was relatively short. Nevertheless, the amount of information the country reporters compiled and the thoughtful interpretations they provided were both impressive.

Twelve reports were subsequently submitted to the Council from countries with a wide range of size, economic development, and scope of physics education. The "country reports" could be considered as a representative group of countries in the Western Hemisphere, if "representativeness" has any meaning in this context, but at least it is a diversified group.

Since the country reporters were the primary authors of this final version, they must be named and thanked here at the beginning. It is a pleasure to do both and they include:

Argentina	Prof. Alberto Maiztegui Universidad de Cordoba
Brazil	Prof. Luis Carlos de Menezes Universidad de Sao Paulo
Canada	Prof. Donald G. Ivey University of Toronto
Chile	Prof. Emilia Martín García Universidad de Tarapaca
Colombia	Prof. Ramiro Tobón Universidad del Valle (Cali)

Costa Rica	Prof. Luz Maria Moya Universidad de Costa Rica
Ecuador	Prof. Abel Alban Escuela Superior Politécnica del Litoral
Guatemala	Prof. Jorge Antillón-Matta Prof. Josefina Antillón-Matta Universidad del Valle de Guatemala
Jamaica	Prof. Neville McMorris University of the West Indies (Mona Campus)
Mexico	Prof. Jorge Barojas Prof. Rafael Rojas Prof. Fernando Urdapilleta Universidad Autónomona Metropolitana-Iztapalapa, Mexico DF
United States of America	Alex F. Burr New Mexico State University
Venezuela	Prof. Celso L. Ladera Universidad Simón Bolivar Prof. Jeanette Lejter de Bascones CENAMEC

The Council on Inter-American Conferences on Physics Education gathered the country reports to meet two goals: 1) preparation of a brief summary of the characteristics of physics education for use as a background document for participants in the Oaxtepec Conferences, and 2) the writing of this more comprehensive report.

Goal I: A Brief Summary for the Oaxtepec Conference

Achieving the first goal was intended to offset a difficulty that participants in international education conferences often have--understanding the differences and the similarities between national systems of education, in conducting their discussions, and in preparing their recommendations. Although the general nature of education in different countries is common knowledge, more detailed information, particularly on physics education, upon which thoughtful analysis can be conducted and practical suggestions offered, is not.

After the "country reports" were submitted to the Council, a summary of the characteristics of physics education in several countries of the Western Hemisphere was compiled shortly before the Oaxtepec Conference and distributed to the participants at the registration. This summary, entitled "Physics Education Notebook," was not more than that, but was intended to meet--and apparently did meet--the first goal described above.

Goal II: Comprehensive Report on Physics Education

The second goal was to put the basic information into more permanent and comprehensive form supplemented, when necessary, with additional information and put into perspective by an introductory chapter and a cross-country summary. This goal serves a long-term need of a wider readership and perhaps, serves as the basis for a more ambitious project that could include information on all the countries of the Western Hemisphere.

The present report got under way immediately after the close of the Inter-American Conference on Physics Education (Oaxtepec, Mexico). It was completed some 14 months later, following an extensive process involving translation of some of the country reports, adaptation, editing, supplementing the data and information, and fitting the information into a reasonably consistent format. On numerous occasions, the country reporters were asked to provide supplementary information or to help in the interpretation of data, and they proved most accommodating. Other physics-educator colleagues throughout the Americas, as well as organizations such as the American Institute of Physics, were asked to help in this task, and with no hesitation whatsoever, they did and will be acknowledged.

Before the organization of this report is discussed, a brief introductory background of previous efforts will be presented.

A Brief Historical Background

During the 60 s, the Organization of American States (OAS) organized a series of activities in the Americas to promote the improvement of education and research, both scientific and technological, as one of the most efficient means for cultural, economic, and social development of the nations known as the Latin American Countries. These events started in early 1960 with a "Summer School" offered at the Institute of Physics of Bariloche, Argentina in January of 1960. Faculty members and investigators from several countries gathered in Bariloche for course work, lectures, and discussions on several areas of physics.

Another major event was the First Inter-American Conference on Physics Education that was held in Rio de Janeiro (Brazil) during June 24-29, 1963. Nineteen nations of the Americas were represented at the Conference together with some representatives from Europe and observers, among others, from the United Nations Educational, Scientific, and Cultural Organization (UNESCO), and National Science Foundation (NSF) and Ford Foundation from the United States.

The Conference was sponsored by the OAS, the Centro Latino-Americano de Fisica (CLAF), the Ministry of Education of Brazil, and Ford Foundation, U.S. Army Element, Defense Research Office-Latin America, the National Science Foundation of the United States, and the International Union of Pure and Applied Physics (IUPAP).

Details of the Conference can be found in the *Proceedings* published by the Department of Scientific Affairs of the Organization of American States.

During the past 25 years or so, many projects, changes, and activities have been taking place in all the nations of the Western Hemisphere. Political and economic changes have had a strong influence, both positive and negative, on the educational systems of the countries in the Americas.

Through the years there have been several regional, local, and major international projects geared toward the improvement of physics education. The United Nations Educational Cultural Organization (UNESCO) conducted several projects in different countries including Brazil, Colombia, the Dominican Republic, etc. The Centro Latino-Americano de Fisica (Latin American Center of Physics) based in Brazil has offered Conferences, established projects, and provided exchanges of faculty members among many countries of the Americas with very little economic resources. Their efforts should be praised.

Other efforts such as the Latin American School of Physics have provided unique opportunities to physicists for exchange of new ideas in several fields of physics. Joint efforts between Latin American countries, the United States, and Europe have been beneficial to many nations. Cooperative efforts by Mexico, Brazil, Argentina, etc. have produced very positive results in physics education.

The most recent of these efforts was the Inter-American Conference on Physics Education (Oaxtepec, Mexico) held in 1987 as noted earlier. The main purpose of the Conference was to create networks of individuals, organizations, and/or government agencies for the improvement of physics education at all levels.

Several national and international organizations sponsored the Conference including the American Institute of Physics (AIP), the American Physical Society (APS), the American Association of Physics Teachers (AAPT), the "Centro Latino-Americano de Fisica" (Latin American Center of Physics, CLAF), the International Center for Theoretical Physics (ICTP), the International Union of Pure and Applied Physics (IUPAP), the U.S. National Science Foundation (NSF), the Organization of American States (OAS), the "Secretaria de Educación Pública de Mexico" (Secretary of Education of Mexico), the United Nations Educational, Scientific, and Cultural Organization (UNESCO), the "Academia de la Investigacion Cientifica de Mexico" (National Academy of Sciences of Mexico), and the Universidad Autonoma Metropolitana de Mexico (UAM).

It is too early to predict the impact of the Conference in the Western Hemisphere. Details of the Conference are included in the *Proceedings* published by the American Institute of Physics (1988).

The first issue of *Networking News*, a newsletter that provides information and encourages correspondence and requests for information of activities on physics education in the Western Hemisphere, was published and distributed in January 1988. The second issue was published in August 1988. The contents of these newsletters indicate that the Conference was not an isolated effort, but it served as a major step in cooperation among the nations in the Western Hemisphere.

Organization of the Contents of this Report

The reports on each of the countries are presented in alphabetical order. The length or number of pages included in each of them do not indicate or relate to the importance of the country. The reader should be aware that in many cases there were not enough data available or it was not possible to obtain more information because of the time available. In other cases, communications were not easy or it was not possible to find additional sources to supplement the information provided by the "country reporters."

A typical chapter of this report normally includes: a) general information about the country; b) description of the educational system; c) data and information on the state of physics education at each of the educational levels (primary, secondary, tertiary); d) description of graduate programs in physics, if applicable; e) efforts to improve physics education in the country under consideration; and finally, f) an analysis on the "professional physicist." There are, of course, slight deviations from this format, but an effort was made to follow it on each and every country.

In many chapters the reader will not find certain data that evidently would be desirable. For instance, it was not possible to include the curriculum or at least a typical curriculum for the first undergraduate degree offered by the institutions of higher education in each ocuntry. Also, the data available on the work done by physicists outside the traditional academic environment was very sketchy in some of the countries. Thus, this report should be taken as a first major step of cooperation among the countries in the Western Hemisphere.

The Council on Inter-American Conferences on Physics Education would like to encourage physics-educator colleagues, institutions, professional organizations, and administrators to collect data on their countries. The data could be sent to the Council or even to the editor of this report. In addition, any remarks or recommendations to add or to correct information as presented will be welcome and will be addressed in the near future. Perhaps the next report on physics education in the Western Hemisphere, if there is one, will include information on all the countries in the Americas.

The final cross-country examination chapter includes a summary of the data and information collected. Some of the remarks included might not be welcomed by some individuals, but it should be noted that the analysis contained in this chapter is based on the available data and the opinion of the editor.

The chapter is intended as a challenge to physics educators and administrators in the Americas for the improvement of physics education and is also meant to enhance cooperation among individuals, groups of individuals, and governments irrespective of political and religious viewpoints and irrespective of the size and economic situation of the country.

The Council on Inter-American Conferences on Physics Education hopes to have a Spanish version of this report which will be based on the "country reports."

Physics Eduction in the Western Hemisphere: Will the Report Be Useful?

Through the completion of this comprehensive report, an attempt has been made to answer such questions as: "What was the report intended to accomplish?", "How was it prepared?", and "Why was some work of this magnitude needed?". There is, however, in the editor's view, one more question to be addressed: "Who will find this report useful?"

The answer to this question might be complex and it will be left to the reader to provide a good answer.

In the editor's opinion, several segments of the Western World might find this report useful as a first step for further cooperation. Thus, those persons and/or organizations who will find the report informative or useful might include:

1) The higher authorities and staff in the Ministries of Education, Science, and Technology, etc. of the countries not only in the Western Hemisphere but also around the world.

2) The higher authorities and staff of international organizations for science and technology, for economic development, etc. such as the United Nations Educational and Scientific Organization (UNESCO), the Organization of American States (OAS), the World Bank, and so on.

3) National groups in physics and physics education.

4) Administrators in universities, technical schools, school systems, etc.

5) Individual physicists and physics teachers with an interest in the development of physics education in their own countries and abroad.

6) Other professionals and concerned citizens in the educational process around the world.

Acknowledgments

It is evident that a report of this magnitude cannot be completed by one person. I want to thank again the "country reporters" for their work and dedication in providing the basis for this report.

Moreover, the country reporters, our physics-educator colleagues in the Western Hemisphere, and I must acknowledge Mrs. Graciela Garcia de Guzman, from Mexico, for developing the outline on which the country reports were prepared.

I am also indebted to Mrs. Maria Elena Khoury from the staff of the American Association of Physics Teachers for serving as a liason between the AAPT office in Washington, D.C. and my office in California. She was always kind and ready to help with my questions, and on numerous occasions she provided me with the appropriate contacts to expedite this project.

I am grateful to the reference librarians of the University of the Pacific, particularly Jo Roullard, Rachel Finch, Nancy Mangum, and Karen Snure, who provided the needed support for the completion of this work.

I want to express my debt of gratitude to Mrs. Celia Nathe, secretary of the Physics Department, for her dedication, patience, and assistance in the preparation of this report. Her roll was more than just typing and re-typing the manuscript. She gave me strong support at times of frustration, gave me advice, made invaluable suggestions on the format of this work, and always offered constructive criticism whenever I requested it.

To the American Association of Physics Teachers, particularly to Dr. Jack M. Wilson, Executive Officer, and to the Council for Inter-American Conferences of Physics, thank you for asking me to serve as Editor-in-Chief of this work. I felt honored in being selected.

I must also acknowledge, and thank on my behalf and that of the physics community, the National Science Foundation of the United States for providing the economic support to complete this comprehensive report.

There were many individuals and organizations who provided excellent advice and invaluable data who should be named and thanked. I must mention Dr. Ted Halpern(Argentina-United States), Dr. Miguel Kiwi (Chile), Dr. Jorge Barojas (Mexico), and Dr. Marcos Moreira (Brazil). I must also thank Ms. Beverly Porter and her staff from the Manpower Division of the American Institute of Physics for the invaluable data they provided. I am grateful to Michael Nueschatz from the American Institute of Physics, who graciously allowed me to use the data and information contained in the preliminary version of their excellent report on Physics in the High Schools (United States).

I feel very fortunate for having my family standing beside me and providing the incentive and moral support I needed for this work.

Last, but not least, I want to thank Dr. William C. Kelly, Executive Secretary of the Council on Inter-American Conferences on Physics Education and Director of this project. His enthusiasm, advice, confidence, and support through these 14 months have provided me with the additional energy needed to complete this report on Physics Education in the Western Hemisphere. To "Bill" Kelly, my eternal debt of gratitude.

Andres F. Rodriguez
University of the Pacific
Stockton, California
U.S.A.

September 1988

ARGENTINA

General Information about the Country

Argentina is the second largest country in South America. It has a surface area of 2.776,889 km^2 or approximately 1,072,157 square miles. The surface area does not include the Malvinas Islands (Faukland Islands), the South Sandwich, South Georgia, and South Orkney Islands, all claimed by Argentina but administered by Great Britian. Argentina also claims one part of the Antarctica.

The country is divided in 22 provinces, one national territory, and one federal district where the capital and largest city, Buenos Aires, is situated. Argentina is separated from the southern part of Uruguay by the Rio de la Plata (one of the major rivers of the Western Hemisphere). It also has boundaries with the western part of Uruguay and South Brazil (separated by the Uruguay River). The Pilcomayo and Paraná rivers serve as boundaries with Paraguay. In the northwest, Argentina is separated from Bolivia by the Andes and the Gran Chaco and on the west the coastline of the Andes serves as the boundary with Chile. The Atlantic Ocean borders Argentina on the east.

Argentina is called the granary of South America on the strength of its exports of wheat, alfalfa, corn, and flax, among others. The livestock industry is very strong, with large meat exports. Argentina has several large commercial and industrialized cities. It has important mineral deposits which include oil, lead, zinc, copper, and uranium. Argentina has several oil refineries and petrochemical plants, producing also coal, natural gas, etc. The chemical industry of the country is highly developed. Electric power is generated by conventional thermal plants, several hydroelectric power complexes, and two nuclear power reactors (Atucha I and Embalse) built with the cooperation of a well-developed native nuclear technology infrastructure.

The population of the country, about 30 million, is overwhelmingly of European descent, mainly of Italian and Spanish origin. The Mestizo population is very small and the Indian population, although declining, is still strong in certain regions of the country. The official language of Argentina is Spanish. The population growth rate is among the lowest of the Spanish-speaking countries. Argentina has one of the highest literacy rates in the Americas (more than 90%), according to U.N. statistics.

The Educational System in ARgentina

The educational system of this country is comprised, at present, of four levels: pre-primary called "jardin de infantes" (kindergarten), primary, secondary, and higher education.

A. Pre-Primary. During the past 30 years this first educational level has been implemented and has extended very rapidly throughout the country. Children attend pre-primary school at the age of four or five. The number of children attending pre-primary school is estimated at 500,000. As the system is being implemented, a new career to prepare teachers for this level has been developed. The career takes about two years, but for any person to start their preparation for teaching, he/she must have completed the secondary school. The number of institutions offering a degree for pre-primary school teachers is about 200 with an enrollment of about 10,000.

B. Primary School. Children are enrolled in this cycle between the ages of 6 through 13 years, and it extends for 7 years, from grades first through seventh. The student population at this educational level is estimated at over 5,000,000, attending over 31,000 schools. The number of primary school teachers with a degree is about 270,000. The career for teaching at primary school level takes four years, and to be enrolled in the institutions offering the degree, the person must have completed his/her secondary education. The number of institutions (private and state-supported) offering the degree for primary school teaching is less than 1000 with an enrollment estimated at 50,000. While it may not be fair to make meaningful comparisons with other countries due to radically different costs of living, income per capita, etc., it is worth noting that the starting salary of a primary school teacher is about 150 U.S. dollars per month. As a point of reference, the Argentine Government estimates the minimum salary for governmental workers at 100 U.S. dollars per month. It is worth mentioning that 95% of the primary school teachers are women. It is also estimated that only 50% of the children enrolled in the primary school system complete the seven grades in this level.

C. Secondary Education. There are 8991 secondary schools in the nation with over 1.8 million students enrolled and approximately 228,000 secondary school teachers. The secondary school system is not uniform and the student enrolled in this level can choose among these options:

1. "Bachillerato," which is a regular secondary school system with 5638 schools, 761,601 students, and 95,869 secondary school teachers.
2. "Comercial" (Commercial Schools), considered as business oriented, with 1974 schools, 611,455 students, and 70,664 teachers.
3. "Técnica" (Technical Schols), with 1013 schools, 391,903 students, and 53,063 teachers.
4. "Agropecuaria" (Agricultural Schools), with 261 schools, 32,675 students, and 6,605 teachers.

5. Finally, there are about 105 schools in other categories with an enrollment of 12,740 students and 28,181 teachers. Evidently most of the teachers are part-time (hourly basis).

In general, the figures indicated in the secondary school statistics might be misleading if we try to establish student/teacher ratio. A large proportion of teachers are not on a full-time basis, working only a few hours per week in more than one institution.

D. Higher Education. There are over 1000 institutions of higher education with 902,882 students enrolled and 69,985 professors. At this level of education, it is necessary to consider two types of institutions: a) universities, and b) non-universities or institutions of tertiary levels as they are called in Argentina.

a) Universities. There are 49 universities, including official or state-supported and private institutions. These universities are comprised of 479 faculties and/or schools. The total enrollment in the universities is 707,016 students with 41,804 professors.

b) Non-university or institutions of tertiary level. There are 978 institutions of tertiary level with a total enrollment of 195,866 students and 28,181 professors.

Physics Teaching at Secondary School Level

The curriculum in the regular secondary school level, known as "bachillerato," includes three courses in physics. During the third year of secondary school a course in elements of physics and chemistry is offered (two hours per week). In the fourth year of their secondary education, students must take a course in mechanics and heat (three hours per week) and during the fifth year, students take a course in optics and electricity which also includes some topics in modern physics (atomic physics). This last course in physics is offered three hours per week. Laboratory work is considered an integral part of these three courses; however, many schools do not have laboratories or the adequate equipment for the experimental part of these courses. As a consequence, the physics courses are mainly theoretical, based on lectures and problem solving.

During the past 40 years, 12 textbooks have been published and used in the secondary school level.

Preparation of Physics Teachers for Secondary Education

During the past 40 years the number of institutions to prepare physics teachers for secondary education has been multiplied by a factor of ten. However, very little has been done regarding the methodology of physics teaching at this level. Projects such as the PSSC, the Nuffield project, and, in particular, the "projecto Piloto UNESCO" (UNESCO Project in Physics) have seldom been officially discussed in these institutions as they did not have any support from the Ministry of Education. The actions to support these innovative projects were promoted by teachers and professors interested in changing the methodology of teaching. The only systematic effort to introduce, for instance, the UNESCO Pilot Project, took place in the School Monserrat of the Universidad Nacional de Cordoba for a period of only two years. It should be understood that while there are some ongoing efforts in the development of new teaching materials, new methodologies, and research in the field of physics, education, the institutions dedicated to the preparation of high school teachers either do not encourage or have not included any of these components in the preparation of teachers.

In 1940 there were about five institutions to prepare physics teachers for secondary education. In 1972 the number had grown to about 49, and in 1983 there were about 59 of those institutions. It is interesting to mention that of those institutions or schools dedicated to preparing secondary school teachers, 30% are located in the universities (about 24% in national or state universities and approximately 6% in private universities). The remaining 70% are affiliated with institutions under direct dependency of the Ministry of Education (Tertiary Level Institution).

Some important data related to the preparation of secondary school teachers follows:

a) Students enrolled in institutions for the preparation of secondary school teachers. The number of students enrolled in these institutions varies. For instance:

   i) 81 to 100 students per year were enrolled in 7% of the total number of institutions dedicated to the preparation of secondary school teachers.
   ii) 41 to 80 were enrolled in 28% of same.
   iii) 21 to 40 were enrolled in 29% of same.
   iv) 1 to 20 students were divided among the rest of the institutions.

b) Graduates for secondary school teaching. The number of students graduating between 1972-79 was:

   i) in about 50% of the institutions the number of graduates was less than 10 secondary school teachers per year.
   ii) in 35% of these institutions this number is between 10 and 20 per year.
   iii) in 1978 about 7% of the institutions did not have any graduates yet. There are no data on the remaining 8% of the institutions.

c) Faculty in the institutions or schools for the preparation of secondary school teachers. All the professors in these schools possess a degree from a university or tertiary level institution, but the number of hours of teaching (lectures) and laboratory work varies from 20 hours per week to less than 10 hours per week.

d) Laboratories and problem solving. According to the data, 40% of the institutions or centers for the preparation of teachers indicated that they have laboratories available. The availability of equipment varies among the different institutions.

In their teaching, about 40% of the professors do not spend any time in laboratory work. The rest (60%) dedicated between 30 to 50% of the course work to laboratory.

Approximately 80% of the professors do not include any problem-solving sessions in their teaching, 6% spend about 10% of their time in problem solving, and the others (15%) dedicate between 5% and 30% of their time to problem solving in their courses.

e) Libraries. It is possible to find some libraries with only 100 volumes while others have more than 20,000 volumes. Also, 73% of the libraries receive scientific journals and 13% do not receive any. There were no data available for the remaining 14%.

f) Innovations in the methodology of physics teaching. According to the data available, about half of the institutions or centers indicated that their students have knowledge of projects such as the PSSC, the UNESCO Pilot Project, the Harvard Project, Promec, etc. This knowledge is acquired through lectures, conferences, or personal contacts with specialists in the field. The survey conducted shows that the students have very limited opportunities to participate in any type of work for the improvement of the methodology of teaching.

Preparation of Teachers for the University Level

The preparation of professional physicists in Argentina or physicists to teach at the university level started during the first decade of the 20th century in the National University of La Plata. It was a very interesting effort, with economical and political overtones. Its development was curtailed by World War I (1914-1918). It should be mentioned that three of the first graduates from this program--R. Loyarte, J. Collo, and T. Isnardi--are authors of some of the few textbooks in General Physics published in Argentina. Around 1930 the career of physicist was established at the University of Buenos Aires and at the University of Tucuman. In 1940 the degree was established in the National University of Cuyo, and in the decade of the 50's in the University of Cordoba and in Bariloche (Instituto Balseiro). The latter was founded by an agreement between the National University of Cuyo and the Atomic Energy Commission of Argentina. At present, professional careers in physics are offered in about a dozen of the national universities.

As historical data it should be noted that until 1954 there were 36 professors with a Doctor Degree from Argentinian universities. The degree, Doctor in Ciencias Físico-Mathemáticas, was awarded to physicists and mathematicians. In 1987 it was estimated that there were 2000 "Licenciados" in physics. This degree is equivalent to a Master of Science and is the first degree that a student in physics can receive from the Argentinian universities. The number of Doctor's degrees granted by these institutions is estimated at 1000.

The number of undergraduate students registered in the career of "licenciado" in physics in 1987 was estimated at about 2000 in the whole country. This number includes students at all levels during their five-year career.

The enrollment in physics courses in the 49 universities in the country (state and private institutions) is about 200,000 per year (includes students in chemistry, engineering, medicine, etc.).

The qualifications of the professors teaching introductory physics courses at the university level vary. It is possible to find some professors without a degree in physics (engineers, physicians, etc.), but all of them have at least a university degree with some basic preparation in physics. However, the number of professors with degrees of "Licenciado" or "Doctor" degree in physics is steadily increasing. The personnel teaching upper-division courses for students in physics do possess the appropriate physics degree.

The textbooks used most frequently in general physics are Halliday and Resnick, Sears, Tipler, Bueche, Borowitz and Beiser, etc. Other textbooks by national authors such as those written by Roderer, Galloni and Ruival, and Giambigi and Bollini are also used.

Efforts to Improve Physics Education at all Levels

One of the most important factors in the improvement of physics education in Argentina was the establishment in 1960 of "full-time professor" positions in the universities. These positions provided better opportunities to the faculty in those institutions to improve teaching and research.

Since then, workshops and courses to update professors at secondary and university levels have been offered in the fields of chemistry, biology, mathematics, and physics. The Science Fairs were established in Argentina in 1966, stimulating students and teachers throughout the country.

Since 1978, national meetings for physics education have been held (Reuniones de Educación en Física) with attendance estimated at more than 1000 teachers per meeting. The Association of Physics Teachers in Argentina (Asociación de Profesores de Física en Argentina, APFA) was established in 1983 as a result of these meetings. A new *Journal on Physics Teaching (Revista de la Enseñanza de la Física)* appeared in 1986.

One of the biggest contributions to the improvement of physics education at the university level and in the modern preparation of the professional physicist was the establishment of the Institute of Physics in Bariloche in 1955. The name was changed to Instituto de Física Balseiro in honor of the first director and founder Jose A. Balseiro after his untimely death. It was a unique effort in Argentina.

Students are selected on a national basis by a selection process which includes very elaborate tests. Students may apply to the program after completion of two years of undergraduate work in a university. It was perhaps the first institution of higher education in Argentina with dormitories. The curriculum was established stressing high academic standards and the faculty, both national and international, was highly qualified. Many of the graduates pursued and received PhD s abroad after completing their education in Bariloche. At present, the institution also offers the Doctor's degree (the first Doctoral degree was granted in 1959) and a degree in nuclear engineering.

Other projects have been organized by the Association of Physics Professors in Argentina, such as:

1. Projects on Methodology and Teaching Physics. It includes workshops and short courses in physics to motivate and give new ideas to physics professors. Jorge Rubinstein and Hugo Tricarico, Buenos Aires.
2. Project on specific topics in physics for the institutions or centers dedicated to the preparation of secondary school teachers. Two workshops on experimental errors and one on heat have been offered. Prof. Felix Mitnik, Córdoba.
3. Exchange of students during their senior year. Profs. Ricardo Romero and Ascensión Macías, San Juan.
4. Publication of the *Journal on Physics Teaching (Revista de la Enseñanza de la Física)*. Prof. Rosa Adam, Rosario.
5. Fifth Annual Meeting on Physics Education (Reunion de la Enseñanza de la Física) in Mar del Plata.
6. Basic and applied research in the physical sciences, toward the theme "conservation of energy," supported by the Ministry of Public Works (Ministerio de Obras Públicas). Prof. Marcelo Zanni, Rosario.
7. Project on Preparation of Videocassettes for Teaching, Prof. H. Ruival, Buenos Aires.
8. Project on the Development of a Doctor Degree in Physics Education. Prof. Leonor C. de Cudmani, Tucumán.

Graduate Studies in Physics and the Professional Physicist

Several universities in Argentina offer graduate work in physics, leading in most cases toward the Doctor degree in several fields, with a level highly comparable to those offered in institutions abroad. The faculty in charge of these graduate programs hold Doctor's or PhD degrees granted by national as well as foreign institutions.

The activities of Argentinian physicists have been changing since 1950 when their professional work was mainly dedicated to teaching. Physicists in Argentina are now involved in research in pure and applied physics and their participation in industry is increasing.

There are several journals in Argentina publishing original research papers in pure and applied physics as well as in physics education. Publications in international journals by Argentinian physicists is estimated at more than 100 per year.

BRAZIL

General Information about the Country

Brazil (Federativa Republica de Brasil) is the fifth largest country in the world and occupies nearly half of South America. It has a surface area of 8,511,865 km^2 or 3,286,470 square miles.

Brazil has borders to the north with Venezuela, Colombia, Guyana, Suriname, and French Guiana. It spreads west to the equatorial rain forests, bordering on Peru, Bolivia, and Colombia. To the south of Brazil are Paraguay, Uruguay, and Argentina. The country has a very long coast line facing the Atlantic Ocean to the east.

Brazil has a great variety of lands and climate. Although the country is mainly in the tropics, climatic conditions vary from hot and wet in the forests of the Amazon basin, to temperate in the southern part of the central upland.

This country is formed by 23 states, three territories, and the federal district of Brasilia, site of the capital city Brasilia.

The population according to 1986 data, was 138,403,000. Many observers consider that the present population is near 140 million. The population growth is estimated at 2% per year. It is expected that the population of Brazil by the year 2000 will be close to 180 million.

The ethnic composition of the population, according to data obtained for 1980, was Brazilian white 53.0% (composed mainly of Portuguese 15%, Italian 11%, Spanish 10%), mulatto 22.0%, mestizo 12%, Black 11%, Japanese 0.8%, indigenous Indian 0.1%, and other 1.1%. Some observers consider that Brazilians are very proud of the new Brazilian "race" as a successful amalgam of Indians, Blacks, and Europeans. Life expectancy at birth (1980-85) was 60.9 years for males and 66.0 years for females.

The official language in Brazil is Portuguese. According to the data obtained for 1985, literacy in the country is estimated at 79.3% with the percentage for males (80.4%) slightly higher than for females (78.3%).

Since World War II, Brazil has experienced rapid industrialization and a high rate of economic growth. In particular, during the 1967-74 period, the Gross National Product expanded at an average rate of 11% per year in real terms. It is estimated that the economy has been growing at an average rate of about 5% (1965-84). Many observers consider the economic growth of Brazil as a surprising phenomenom, particularly if one takes into account that the country has one of the largest foreign debts in the world and the yearly inflation rate has continued to rise, reading 234% in 1985.

Many Brazilians also consider that the economic growth has not resulted in better welfare conditions for the general population of Brazil.

Agricultural production provided about 40% of the country's export earning in 1983. The principal agricultural exports are coffee, sugar, soybeans, orange juice, beef, poultry, and cocoa. Other crops include tobacco, corn, sisal, and cotton. Brazil has experienced several problems in agriculture due to severe droughts (1985), lack of investment, floods, and restrictions of imported fertilizers, among others. A new Development Plan (1986-89) was announced to develop the agricultural sector to meet the domestic demand for food.

Industrial production is concentrated on vehicle production, machinery, electrical goods, construction materials, rubber, sugar, wood processing, steel production, and chemicals. Many of the traditional industries, such as textiles, clothing, food, and beverages, still play an important role in the total industrial production. In 1983, manufactured goods accounted for about 54% of Brazil's exports.

Mineral reserves in Brazil are very large, and the leading mineral export is iron ore. However, new discoveries are being made, including uranium, gold, manganese, titanium, copper, and coal, to mention a few.

Some discoveries of crude petroleum have reduced the dependence on imported oil, and offshore exploration has revealed some natural gas reserves. About 95% of Brazil's total electric energy consumption was hydro-generated in 1986. After the discovery of uranium deposits, Brazil signed an agreement with the Federal Republic of Germany to build eight nuclear power plants. The program has suffered some delays. Only one plant was completed in 1983 and commenced operations in 1985. Developments in nuclear power have been postponed due to the government's austerity program.

Illiteracy is still very high in spite of Brazil's industrialization and economic growth. Literacy estimated at 79% total is very low in the rural areas (about 50%), while it is relatively high in urban areas (about 85%). The Brazilian population at present is about 70% urban.

Educational System in Brazil

Many observers consider that the social and economical differences between the different regions in this country together with the migration to the cities have had a tremendous impact on Brazil's development. The northeast, southeast, and south areas of Brazil are inhabited by 90% of the total population. The southeast, where the cities of São Paulo and Rio de Janeiro are located, comprises only 11% of the total area of Brazil but it has about 43% of the total population and almost the whole industrial production (70% of the Gross National Product). The northeast region, on the other hand, accounts for 18% of the total area of the country and 29% of the total population. However, it does not contribute more than 10% of the GNP. The north and west regions of Brazil, with 64% of the total area of the country, are very weak economically and the population density is very low. The south, not as rich as the southeast, is socially and economically above national averages.

The growing urbanization and industrialization together with the population growth has increased the demand for better education at all levels. Well-informed observers blame the absence of a sound state policy for the deterioration of public education. In many sectors, it has resulted in the increase of private institutions which have reasonable standards at the elementary and secondary level but vary at institutions of higher education.

The educational system in Brazil is comprised of three levels: elementary, secondary, and higher education.

A) Elementary School Level

Since 1971 this first level has consisted of eight years of schooling (grades one through eight). It combines the four years of elementary school and four years of gymnasium, which comprised the old first level of education. The old subdivision is still reflected in the new system.

During the first stage of the new system (first four years), children attend classes four hours daily under the direction and supervision of one teacher. Essentially, children learn to read and write. They also learn some basic arithmetic, notions on measurements, geography, history, and simple topics in science. Biological topics are dominant in the science component, including general notions on hygiene and studies on plants and animals and their environment. Topics on the solar system, without any emphasis on gravitation, are also included.

Observations and classifications are sometimes exercised in class; but in most cases, according to Brazilian observers, the emphasis is placed on memorization of the topics being studied.

During the second stage of the elementary school level (last four years), there are separate classes offered in Portuguese, mathematics, geography, science (which includes some physics), etc. with one teacher assigned to each of the subjects. Classes are offered four hours a day at this stage.

Children normally enter the elementary school level at the age of seven and should finish it by the age of 14 or 15. However, it is possible to find people in Brazil who by the age of 18 have not yet completed their elementary education.

The total number of elementary schools is estimated at about 190,000 with 95% of them supported by the government (public schools). However, this figure might be misleading because many of these schools are small units that offer only the first four years (first stage) of the elementary school level.

The number of teachers at this first level of the educational system is about one million (85% of them at public schools), but a more realistic figure places the number of teachers at 900,000. According to the data available, 25% of these teachers have not received any formal teacher preparation.

The number of students in the elementary school level is estimated at about 25 million, with 85% of them enrolled in public schools. Table 1 shows the approximate distribution of students per grade (1985).

Table 1. Distribution of the Student Population in the Elementary Education Level (1985).

GRADE	1	2	3	4	5	6	7	8
NO./STUDENTS (MILLIONS)	7.5	3.8	3.0	2.6	2.4	1.8	1.4	1.1

Some observers in Brazil consider that while this level is officially mandatory, a small number, estimated at 870,000 per year, will complete the elementary school level (80% of them in public schools). From Table 1 it is possible to assume that less than 50% of the children entering this level complete the second grade. The dropout rate is very high throughout the elementary school level.

B) Secondary School Level

The secondary school level in Brazil takes about three years to complete, except for a relatively few schools where four years are required for graduation. Some informed sources in Brazil consider that the educational content at this level has its main focus directed toward the preparation of students for the higher education level.

On the average, the student at the secondary school level will spend about four hours daily (five days a week) in school. It is estimated that about twelve subjects are being taught at this level which are grouped as follows:

i) Communication and Expression (4 subjects) offered six to eight hours per week.
ii) Social Studies (4 subjects) offered also four to six hours per week.
iii) Sciences, which includes mathematics, physics, chemistry, and biology. These subjects are offered eight to thirteen hours per week.

Physics is mandatory at the secondary school level and is taught two or three hours per week during three years. However, some schools do not offer the third year of physics for students who intend to pursue careers in the humanities, medicine, or arts.

The number of secondary schools in Brazil is estimated at about 8,900 (55% of them are public schools). The number of secondary school teachers, according to official figures, is about 215,000. Some observers consider that these figures might be misleading, because many teachers work in more than one school to supplement their incomes. A more realistic figure places the number of secondary school teachers at about 150,000.

The number of secondary physics teachers is estimated at about 8,000, but it is considered that 40% of them are not graduates in physics.

The enrollment of students at the secondary school level is estimated at about 3 million (60% of them attending public schools), distributed as shown in Table 2.

Table 2. Distribution of the Student Population during the Three Years of the Secondary School Level (1985).

	GRADE		
	1st year	2nd year	3rd year
APPROX. NO./STUDENTS ENROLLED IN MILLIONS	1.3	0.9	0.7

According to the statistics provided for this level, about 600,000 students complete their second educational level every year. This estimated figure also indicates that the dropout rate in secondary schools is very high with the physics and mathematics courses being responsible, up to a point, for these figures.

Some observers consider that the preparation of graduates from the secondary level is insufficient. Most of the graduates spend at least one extra year preparing for the entrance examination required by the universities in Brazil. These "preparation courses" are not free and are offered by private parties or schools.

However, there are some schools, with better trained teachers, which emphasize the preparation of the student for the higher education system. Consequently, the graduates from these schools are better prepared for the entrance examination in the universities. These schools and the "preparation course" previously mentioned are expensive and many Brazilians are unable to afford them.

C) Higher Education Level

There are 847 institutions of higher education in Brazil, with about 65 of them considered universities (70% of which are known as public universities). Most Brazilian public universities are supported by the central government and are called federal universities. Some states, such as São Paulo, have their own university systems.

The number of faculty members at these institutions is estimated at about 120,000, with 55% of them working at public institutions.

According to 1985 data the enrollment of students in the higher education level is approximately 1.5 million, with 40% of the students attending public institutions. In general, enrollment in Brazilian universities is limited, especially in the public universities which are tuition free. An entrance examination is required for those students applying for admission. It is estimated that 2.2 million students apply every year for about 335,000 new places. However, according to the data provided by some observers, only about 267,000 pass the entrance exmaination. The number of graduates per year is estimated at about 238,000.

Graduate degrees were introduced in Brazil during the 60s and the number of students obtaining these degrees has been growing steadily since then. The quality of these degrees varies among the institutions.

According to the data provided, there are about 800 graduate programs being offered in Brazil leading to a Master's degree and approximately 300 programs for Doctoral degrees. Ninety percent are offered at public institutions.

A PhD degree or an equivalent Doctor degree is required for faculty members teaching at graduate level. The total number of faculty members holding a Doctor degree is estimated at 20,600. The majority of them (90%) are teaching at public institutions.

Table 3 shows some statistics related to enrollment in graduate programs and degrees granted every year. The figures given are approximate.

Table 3. Statistics on Graduate Programs.

No. enrolled in Master's prog.	No. enrolled in Doctoral prog.	Master's Degree granted/year	Doctor's Degree granted/year
28,000	5,800	3,800	560

Physics Education at the Elementary and Secondary School Levels

During the first four years of the elementary school level, children are exposed to some simple topics in science, but as previously mentioned, they are usually oriented toward the biological sciences except, for instance, for some brief descriptions of the solar system.

The main problem is that the teachers for this first stage are prepared through programs known as "Magistério." These programs are modified versions of the secondary school level. The science component is very weak and rarely includes any physics. In addition, the textbooks for this level of education superficially treat topics in physical science.

During the second stage of the elementary school level, where there is a teacher for each subject who is supposedly better prepared, courses in the sciences are offered. There are official programs for each subject including science, but Brazilians consider that the amount of physics actually taught depends on the teacher and the textbook chosen. The preparation of the secondary school teacher is again an important factor in the amount of physics taught at this level.

It is worth mentioning that while teachers for this stage (grades five through eight) are prepared in the universities, the majority have a major in biology. Physics teachers who do not have courses in the biological sciences are not allowed to teach science. On the other hand, the physics component included in the textbooks is usually superficial and includes some scattered topics such as average velocity, atmospheric pressure, temperature, electric currents, and so on. These topics are treated with inadequate mathematical formalism.

Well-informed Brazilian observers consider that the teachers are not well prepared to select their textbooks and, consequently, books with a poor pedagogical approach and content might be selected.

Many teachers, who recognize their lack of preparation, simply drop the topics at their convenience. There are some exceptions; in fact, some schools adopt a well-balanced curriculum in science and have well-trained teachers. Moreover, there are many pilot projects funded by the Federal Government in Brazil to improve science teaching (190 in 1987). These projects are mainly dedicated to enhancing laboratory activities and to stressing the connection between classroom and real life situations.

In the secondary education level, physics is mandatory. Students must take three years of physics, which is taught three to four hours per week.

During the first year of this level, students normally should take mechanics and thermodynamics. Optics and electromagnetism are scheduled for the second and third year. However, in most schools, students are taught kinematics and dynamics of single particles during the first and second year. The third year of physics is assigned to electricity and magnetism, but it mainly includes some electrostatic and direct current circuits. In some cases, topics in geometrical optics are included. Thermodynamics is virtually not included in the courses, except for the use of scales of temperature and thermal expansion. Topics such as real circuits and electrical components are almost non-existent in the curriculum. Needless to say, modern physics and physical optics are rarely included. The physical facilities for laboratory work are available in many schools, but most teachers have no time to use them or lack the basic preparation to introduce laboratory experiments in their physics courses.

Some well-informed observers consider that the main factors responsible for the situation of physics education at the secondary level are:

1) Poor preparation of the secondary school teachers in physics, even if they have the appropriate credentials.

2) A large number of persons teaching physics do not have any formal training in the subject. Many of the teachers have degrees in mathematics, chemistry, or biology, and it is even possible to find engineers teaching part time. This number can be as high as 50% in some regions of Brazil.

3) The entrance tests required for admission into the higher education level do not stress conceptual understanding in the sciences.

4) Textbooks are published and chosen without any control of their pedagogical approach and of their physics content.

Physics Education at the Higher Education Level

The role of physics at this level depends strongly on the nature of the programs for which it is offered.

Introductory physics courses are mandatory for almost all the branches in engineering. Students majoring in the field take up to four semesters in physics (six hours/week). In addition, physics courses are required for those enrolled in programs in the physical and natural sciences such as geology, chemistry, biology, physics, and so on. For the past 20 years, since a reform took place in the higher educational system, all the courses in physics are housed at physics institutes and/or physics departments of the institutions of higher education and, consequently, they are taught by physicists.

The contents and level of these introductory courses vary according to the programs or major areas for which they are offered. However, courses such as "Physics for Biologists" might be offered relying on textbooks published for different areas of concentration.

Some Brazilians consider that the improvement of physics teaching at the university level has been jeopardized by the attitude assumed in certain universities where the physics professor is judged mainly by the number of published papers rather than by his/her teaching. In other institutions of higher education(isolated third-level schools), the professor is paid by the hour (hourly basis) and, as a consequence, it is not possible for him/her to improve the standards as a scientist or as a teacher. However, their situation is not uniquely Brazilian since teaching is not rewarded as it should be in most of the countries around the world. Also, the two main problems previously mentioned as obstacles in physics teaching cannot be generalized to apply to all the institutions of higher education in Brazil.

The standards for undergraduate education programs for majors in physics vary among the universities in Brazil. At present, there are about 44 programs among the 64 institutions of higher education where research on physics education is being conducted. Some of these programs are quite acceptable according to international standards. In particular, there are about ten universities where classes, textbooks used, and laboratories are comparable, for instance, with those at a European or an American unviersity.

The production of textbooks for the higher education level in Brazil is still very limited, and about 90% of the adopted textbooks are translations. A large amount of the materials in laboratories are produced locally and usually the laboratory instructions vary among the institutions.

In a typical undergraduate program in physics in Brazil, the first two years are used for fundamentals in classical physics and calculus courses. During the last two years of the physics curriculum, students receive upper division courses in modern physics, mathematics, and other advanced courses in physics. For students interested in a teaching career, courses in education are included in their curriculum.

There are two main types of undergraduate degrees in physics granted by the Brazilian institutions: a) Bachelor's degree for students interested in pursuing a graduate degree, and b) "Licenciatura" offered for the preparation of secondary school teachers.

There is a special type of program known as "habilitation" given to science teachers which includes some training in physics, but some Brazilians consider that the results have not been very successful.

According to the available data, 75% of the 44 programs in physics are offered in public institutions. The total number of physics faculty members is estimated at about 1200, but there are another 800 members of the faculty teaching service courses for majors other than physics.

The enrollment of students in undergraduate programs in physics is about 9,700. More than 2,000 new students are admitted every year, but this figure is small compared to the number of new places available which is about 3,000.

Table 4 shows some statistics about the undergraduate programs in physics (source 1985).

Table 4. Undergraduate Education in Physics in Brazil (figures are estimated).

AUTHORITY RESPONSIBLE FOR ADMINISTRATION	NO. OF PROGRAMS	NO. OF STUDENTS	NO. OF GRADUATES PER YEAR
Federal Government	21	4700	220
State Government	7	2500	200
City Government	2	400	20
Private	14	2100	270
Totals	44	9700	710

As indicated in Table 4, 710 students receive an undergraduate degree in physics every year. Of these students, 270 graduate with a Bachelor's degree, 200 receive the degree of Licenciado (Secondary School Teachers), and 240 science teachers for the first level are granted a certificate to teach physics at secondary level after additional training in physics is completed.

The number of graduates in physics is small compared to those receiving degrees in other areas. The situation is similar to that in other western countries due to limited job market, difficulty with the subject, and low salaries.

Although after graduation some of those majoring in physics may find a place in better-rewarded fields such as system analysis, industrial technical assistance, administrative assistance, and specialized journalism, universities and schools are by far the main employers of physics graduates. Universities, however, tend to hire only those with an advanced degree.

Preparation of Teachers for the Elementary and Secondary School Levels

Teachers for the first stage of the elementary level (grades one through four) are not prepared in the institutions of higher education as previously mentioned. They normally graduate from special programs called "Magistério" which are a modified version of the secondary school system.

Teachers for the second stage of the elementary level (grades five through eight) are prepared in the higher education level but using a shortened version of the degree known as "Licenciado." Some of these teachers are accredited to teach physics at secondary level if they take some special training or courses in physics. It should be mentioned that teachers with a physics degree, even if they also have the "Licenciado" degree, are usually not allowed to teach at this level unless they also have taken some courses in biology.

Physics teachers at the secondary level should have the degree of "Licenciado" granted by the institutions of higher education, but it is still possible to find many engineers and others teaching part-time at this level. It is estimated that out of the 8000 physics teachers in secondary school level, about 40% of them are not graduates in physics.

Graduate Programs in Physics

Graduate programs were introduced in Brazil mainly during the 60s but they have grown very fast. In the particular case of physics, the graduate programs are usually of very good quality with high standards. The programs are quite homogeneous for all the institutions which offer graduate degrees.

The master's degree in Brazil is similar to the German "Diplom" or to the French "Troisiéme Cycle" doctor degree.

Graduate students, in addition to their course work which might include quantum mechanics, electrodynamics, solid state, nuclear phsyics, etc., are normally required to complete some original scientific work to demonstrate their familiarity with the chosen branch of physics.

The doctor degree in Brazilian universities is equivalent to the internationally accepted PhD. The program requires completion of an original doctoral thesis, acceptable for publication in international journals in physics.

The number of graduate programs in physics in Brazil is about 18 with 95% of them offered in public institutions. Fifteen of these programs are located in universities and the other three are offered in research institutes authorized and supported by the government.

Presently, it is estimated that the enrollment of students in Master's programs is about 800 while 600 are pursuing PhD programs in physics. The numbers of graduate degrees granted are about 170 Master's of Science and yo PhDs per year.

Efforts to Improve Physics Education in Brazil

The efforts to improve physics education in Brazil received additional momentum early in the 60s. A major project undertaken was the development of the UNESCO Pilot Project "Fisica de la Luz" (Physics of Light). The project was mainly supported by UNESCO and physicists from several nations, particularly from Brazil and several of the Spanish-speaking countries, participated in it. Teaching materials, audiovisuals (film-loops), and inexpensive laboratory equipment were developed in this project and, at present, many countries are still using parts of it.

Many well-informed observers from Brazil consider that the landmark of the truly Brazilian efforts to improve physics education was the First National Symposium on Physics Education held at the University of São Paulo in 1970. An ever-growing movement was originated in this event: Additional symposia were held every three years, curriculum projects were developed, textbooks and other instructional materials were prepared, physics education journals were created, and graduate programs in physics education were offered.

The national symposia are now held every two years and are sponsored by the Brazilian Society of Physics and governmental agencies. About 600 high school and college teachers attend these meetings which include workshops, minicourses, paper sessions, roundtables, and related activities.

The Brazilian Society of Phsyics has a Secretariat for Teaching Affairs which, in a sense, plays the role of an association of physics teachers. The Secretary for Teaching Affairs is an active physics educator and is a member of the Board of Directors of the Society. The Society, in addition to sponsoring the symposia and other activities designed to improve physics education, publishes a journal--Revista de Ensino de Fisica (Journal for Physics Teaching)--entirely devoted to physics instruction and to research on physics teaching. Another journal--Caderno Catarinense de Ensino de Fisica (Catarinense Journal of Physics Teaching)--is published at the Federal University of Santa Catarina.

In the early 70s, probably following an international trend started with PSSC, several curriculum projects were developed. Among them the project Projecto de Ensino de Fisica, known as PEF (Project of Physics Teaching), carried out at the University of São Paulo occupies a prominent position for its quality and completeness. Although it is not a general trend anymore, new curriculum projects currently are being developed.

Also in the early 70s, two masters programs in physics education were created, one at the Federal University of Rio grande do Sul and another at the University of São Paulo. More recently, a third graduate program in physics education was started at the Federal Fluminense University. Closely related to the establishment of these programs was the consolidation of research groups in physics education. Well-established groups exist now at the University of São Paulo and at the Federal Universities of Rio Grande do Sul, Rio de Janeiro, Fluminense, and Santa Catarina. In addition, new groups are being created in different parts of the country.

Most of these activities are directed toward high school and introductory college physics, including both in-service and pre-service teacher preparation.

Summing up, efforts to improve physics education in Brazil seem to follow the same pattern found in well-developed countries: curriculum and instructional materials development, national meetings, journals, graduate programs, and research on physics education. However, these activities are still being carried out on a small scale compared with the nation's needs and, since Brazil is such a large country with so many contrasts, their impact on the improvement of physics education is not significant yet.

The Professional Physicist

The main activity of the Brazilian physicists is academic with research in physics playing an important role in some of the major universities and institutes.

Research in physics in this country can be traced back to 1934 in São Paulo when research on cosmic rays was started. Shortly thereafter, work on dielectric materials was initiated in Rio de Janeiro. In both cases, the research groups were led by European physicists invited to stay in Brazil. During the 1950s there were about six groups doing research in physics, and some Brazilian physicists were working abroad in cooperative projects.

Nuclear physics became the most important field during the 60s, but during the 70s solid state physics became the main field of interest among the research groups. At present, investigations are conducted in several fields but still about 40% of the research, both theoretical and experimental, is done on condensed matter physics. In addition, there are an increasing number of groups of physicists dedicated to work in physics education, making solid contributions both at national and international levels. There are some groups working in interdisciplinary areas which are trying to produce changes in the educational system at all levels.

Well-informed sources consider that there are about 700 PhDs and perhaps a similar number of physicists in possession of the Master's degree employed by universities and/or research institutes. during the past few years the opportunities for academic work became very limited and, consequently, many physicists are moving into other types of activities where salaries and opportunities are better.

It is worth mentioning that most of the work in physics is conducted in institutions located in the most developed regions of Brazil. According to the data provided, 34 of these institutions are located in the southeast region of the country. Thirteen are in the northeast, eleven in the south, four in the west-center, and only two in the northern region. Most of these institutions were established during the past ten years and only about ten institutions have been operating for more than 20 years.

Brazilian observers consider that the interaction between science and technology is still very limited considering the size and industrial development in the country, but physicists in Brazil have been making contributions to industry in fields such as cryogenics, metallurgy, geophysics, the optical industry, aerospace activities, medicine, and microelectronics.

There are several institutes and centers dedicated to pure and applied research in physics such as the "Centro Brasileiro de Pesquisas Fisicas"

(Brazilian Center for Physics Research) and others dedicated to research and development in technology such as "Centro de Pesquisas e Desenvolvimiento" (CEPED)(Research and Development Center). The Comissao Nacional de Energia Nuclear (Commission for Nuclear Energy) in Rio de Janeiro which has several institutes attached, namely: a) "Instituto de Engenharia Nuclear" (Nuclear Engineering Institute) in Rio de Janeiro, b) "Instituto de Radioprotecao e Dosimetria" (Radiation Protection and Dosimetry Institute) in Jacarepagua (Rio de Janeiro), c) "Instituto de Pesquisas Energéticas e Nucleares" (Energetics and Nuclear Research Institute) in São Paulo, and d) "Centro de Energia Nuclear na Agricultura" (Center of Nuclear Energy in Agriculture) in Rio de Janeiro.

Other centers dedicated to technological research and development include:

1) "Fundacão Instituto Tecnológico do Estado de Pernambuco" (ITEP) (Technological Institute of the State of Pernambuco) in Recife.

2) "Instituto Brasileiro de Petróleo" (Brazilian Institute of Petroleum) in Rio de Janeiro.

3) "Instituto de Pesquisas Espaciais" (INPE) (Institute for Space Research) in São José dos Campos.

4) "Instituto de Pesquisas Tecnológicas do Estado de São Paulo" (Institute for Technological Research) in São Paulo.

5) "Instituto Nacional de Tecnología" (National Technological Institute) in Rio de Janeiro.

In all these centers the participation of physicists has been increasing.

CANADA

General Information about the Country

Canada is one of the largest countries in the world, second only to the Soviet Union. It occupies the northern part of North America excluding Alaska and Greenland) with a total surface area of 9,970,610 km^2 or approximately 3,849,675 square miles. Canada extends from east to west from the Atlantic Ocean to the Pacific. In the northwest it has boundaries with Alaska and to the south a long boundary separates this country from the United States of America. The total population, according to the data available for 1986, was 25,638,000, but most of the country has a very low density of population. The majority of Canadians live within 200 miles of the long Canadian-United States border because of the climate in the northern part of the country. The ethnic origin of the population (1981) was British 40.2%, French 26.7%, German 4.2%, Italian 3.1%, Ukrainian 2.2%, Dutch 1.7%, other European 8.5%, Asiatic 2.1%, Amerindian and Inuktitut (eskimo) 1.7%, multiple origin and other 9.7%. The birth rate per 1000 population (1985) is 14.9, almost one half of the world average of 29.0. The life expectancy at birth (1983) was 73.0 years for males and 79.0 years for females.

Canada is divided into ten provinces and two territories. The capital is Ottawa. It is a bilingual country with English and French as the official languages. All federal government documents are published in both languages. In practice, the main working language in one province (Quebec) is French, and in the other nine provinces it is English, but there is a provision in each province for education in the minority language.

Canada is one of the world's leading trading nations. In 1985 it was the seventh largest exporter and the world's eighth largest importer. The Canadian economy, however, is closely linked to that of the United States. Several sectors of the Canadian industry rely heavily on foreign investments but this control has declined in the past few years, mainly as a result of government and private-sector acquisitions.

Canada is one of the most industrialized countries in the world but it is also a major exporter of agricultural products. The main exports (1985) were motor vehicles and parts, crude petroleum, softwood lumber, natural gas, wheat, and wood pulp. In terms of value, Canada is the world's leading fish and seafood exporter. The country is very rich in minerals being the world's largest producer of zinc and the second largest of asbestos, nickel uranium, potash, gypsum, sulfur, and titanium concentrates. Canada is also rich in gold, silver, iron, copper, cobalt, and lead. It has considerable petroleum and natural gas resources.

The Educational System in Canada

The origins of the educational system in Canada are European with major influences from Great Britain and France.

The federal government in this country has little power in the educational system. The British North America Act specifies that education in Canada is a provincial responsibility, not a federal responsibility, and this right has been carefully guarded by the provinces. The federal government, however, runs schools for Indian children, for servicemen overseas, and for prison inmates.

The federal government does make major financial transfers to the provinces for the support of post-secondary education, but does not have a voice in how these funds are used. There is no national office of education, no federal ministry. Each province has a Ministry of Education. In some cases this office includes post-secondary education, but in four provinces there is a separate Ministry for Higher Education.

The educational system in Canada is comprised of the traditional levels: pre-school, first level (primary education), second level (secondary), and third level (higher education).

The educational policy and the period of compulsory education are slightly different in each province but these differences are not fundamental, because Canadian students must be able to transfer routinely between schools and universities across the country. However, since the data could only have been obtained by approaching the ten Ministries of Education individually (one in each province), a large portion of the report will be related to one province, Ontario, as an example. About one third of the Canadians live in Ontario, a very industrialized province, so a factor of three will give reasonable estimates for Canada. Moreover, the educational system is not different from the other provinces except in a few idiosyncratic ways.

It should also be noted that during the 80s all provinces in Canada are actively involved in reforms of the science curricula, as well as in organizational changes, and some of the information on this country might become obsolete as it is being written.

Pre-School

In general, pre-primary education consists of daycare centers, nursery schools, and kindergarten. Many of the daycare centers are privately owned but licensed through the Departments of Education or Social Services. Some school boards provide public education for three and four year olds. Kindergartens (pre-primary education) for five-year-olds are provided in most of the provinces.

Elementary and Secondary Education Level

The average length of elementary-secondary school programs is 12 years. Most Canadian children are legally required to attend school for about ten years; each province has a minimum age (6 or 7) and a maximum age (15 or 16) for compulsory attendance. Ontario and Quebec are exceptions to the norm of 12 years of schooling--Quebec has 11 grades, while Ontario traditionally has had 13. In Quebec, after grade 11 many students proceed to a CEGEP (College d'enseignement general) for a two-year course leading to university or a three-year occupational course leading to employment. In Ontario a secondary school diploma is awarded at the end of grade 12, and is the usual admission requirement for community colleges (2- or 3-year programs). At the end of grade 13 an "honours" diploma is awarded, and this has been required for admission to universities. Because historically grade 13 was intended to be the equivalent of first-year university, the universities in Ontario offer three-year degrees in arts and science, although most university programs require four years. The Ontario secondary system has been under review, with new courses being developed, and it is expected that by 1988 most students will be able to complete the requirements for university entrance by the end of grade 12.

The traditional Ontario program has been divided into elementary (K-8: kindergarten, entered at age 5, and grades 1 to 8) and secondary (Grades 9 to 13). The ministry now divides the educational program into four divisions:

Primary:	Grades K-3
Junior:	Grades 4-6
Intermediate:	Grades 7-10
Senior:	Grades 10-13.

By 1990 the Senior Division will include grades 11 and 12 and the Ontario Academic Courses (OACs), advanced level courses required for university entrance.

In Ontario, about 95% of children entering elementary school go on to enter secondary school (grade 9). Of those entering grade 9, about 30% drop out before completing grade 12, 20% go on to community colleges (after grades 12 or 13) and a roughly equal number (about 18%) go on to a university after grade 13.

At an earlier time, there were province-wide examinations in all provinces at a variety of levels. Over a five-year period beginning in 1968, seven of the ten provinces discontinued the use of provincial examinations to determine student progress through, and graduation from, the secondary system. Examinations controlling graduation from elementary school and entrance to secondary school had been discontinued much earlier. In recent years there have been concerns about two problems: difficulties in determining whether the quality of education was being maintained by local schools and boards, and the perception by some post-secondary institutions that there was no consistent basis on which to admit students. There has not been a return to a system in which admittance to post-secondary education is based totally on a set of external provincial examinations, but there has been some reintroduction of external criteria, in a variety of ways. Alberta and British Columbia, for example have re-established central examinations at the end of secondary school; marks from these determine 50% of a student's final grade, and the school determines the other 50%. In Saskatchewan, on the other hand, teachers who have special certification may assess their own students, while the students of other teachers must write provincial examinations for final secondary courses. Quebec maintains a system of central examinations for all obligatory courses in the last two years of secondary school. In Ontario there have been strong pressures to revive provincial examinations, but at this time student final marks are still determined by the local school. To assist in evaluation, Ontario and other provinces have established pools of assessment items for use by the schools.

A brief description of evaluation has been included because it serves as an example of the diversity that is an integral part of the Canadian educational system.

In 1983 in Canada as a whole there were over 15,000 schools, of which 90% were public, 7% private, and 1% federal (for army personnel, for example). Student enrollment in elementary and secondary schools in 1983 was nearly 5 million, about 10% of these in kindergarten or pre-elementary level, the remainder equally divided between elementary and secondary. The median size of elementary schools is 100-200; for secondary schools it is 500-1000.

Enrollment in elementary and secondary schools reached a peak in 1968-59 and has been declining steadily since, at an annual rate between 1 and 2%; it is expected to slow to less than 1% during the 80s. Table 1 shows enrollment indicators in schools by province and for Canada for 1982-83.

Table 1. Enrollment indicators in schools in Canada. (Source: Statistics Canada).

Province	Median years of schooling attained by population over 14 years	14-17 year olds enrolled related to 14-17 age group	Grade 12 enrollment related to Grade 2 enrollment in 1972-73	High School graduates related to Grade 12 enrollment
Newfoundland	10.5	76.1%	75.8%	67.3%
Nova Scotia	11.2	88.4%	69.2%	80.1%
Prince Edward Island	10.9	86.7%	77.2%	84.0%
New Brunswick	11.0	86.6%	77.5%	88.6%
Quebec	11.4	75.1%	92.2%	82.5%
Ontario	12.1	92.2%	86.8%	81.6%
Manitoba	11.4	87.7%	83.8%	79.2%
Saskatchewan	11.4	86.9%	76.5%	80.3%
Alberta	12.3	82.8%	79.7%	73.4%
British Columbia	12.3	88.8%	80.1%	83.0%
CANADA	11.8	85.2%	84.4%	80.9%

Note that in 1982-83 enrollment in grade 12 was 84.4% of grade 2 enrollment ten years earlier; this figure compares with 52% in 1966-67 and 71% in 1972-73.

Enrollment rates for children between 6 and 14 are assumed to be 100%. Rates are reported for the 14-17 age group because children who have passed their 14th birthday may obtain release from compulsory schooling for extenuating circumstances such as family need.

Higher Education System in Canada

The tertiary level of education in Canada is composed of degree-granting institutions (universities) and non-degree-granting institutions which award only diplomas (community colleges).

There are 66 universities and 197 non-university institutions of higher education (community colleges) in most of the provinces. However. in some cases they are known as Colleges of Applied Arts and Technology (CAAT), Regional Colleges and, in Quebec they are called "Collèges d'enreignement général et professionnel." For comparison, in 1960 there were only 40 degree-granting institutions (universities) and about 30 other institutions of higher education.

The median size of community colleges is 1000 to 3000 students (sizes range from 100 to 10,000), and the average size for universities is 10,000 to 20,000 students.

In 1983 there were 700,000 students in full-time attendance at the higher education level and in addition, 270,000 were enrolled part-time in university degree programs.

In contrast with the elementary and secondary school enrollment, the post-secondary enrollment rose steadily during the 70s at an annual rate of nearly 5%; between 1970 and 1980 it jumped 42%, and increased a further 15% between 1980 and 1983. While it was anticipated that a decline would begin in the 80s, this has not yet been observed.

Essentially all universities in Canada are public institutions--i.e., are financed primarily by public funds through the government.

The five largest universities in Canada are the Universities of Toronto, British Columbia, Alberta, Montreal, and McGill University. The University of Toronto is the largest university in Canada, with a full-time enrollment exceeded by only four universities in the United States. There is a total faculty of about 4,000 and a total student enrollment, including part-time, of over 50,000. The Department of Physics has about 60 faculty members at the three professorial levels.

The largest group of universities offer instruction in English, but in addition to these and the French language institutions, there are some bilingual universities such as the University of Ottawa and Laurentian University.

The universities in Canada provide undergraduate (Bachelor's degree) and graduate degrees in several areas. They also offer professional degrees in law, medicine, architecture, and business administration which normally requires an undergraduate degree in arts or sciences. Engineering and education are sometimes offered as a first undergraduate degree; sometimes they are second degrees. Most universities are organized into faculties, each headed by a dean. Faculties are subdivided into departments in the same manner as the United States universities.

The community college system in the province of Ontario has developed over the past 25 years and enrollment has gradually increased. Recently, the enrollment in the community colleges is exceeding that of the universities.

In some provinces (Alberta, British Columbia, and Quebec), the community colleges offer the first two years of university level, after which students may transfer to a university. They also offer vocational programs. In other parts of Canada they provide technical and/or vocational preparation as an alternative to university. In Ontario the community colleges are not designed as university-feeder systems but rather as separate career-oriented educational institutions offering technical programs in several areas.

During the 70s the technical and vocational institutions (non-university) developed rapidly in Canada. The pattern varies between provinces and even within provinces. Post-secondary institutes of technology require high-school graduation for admission and offer a wide variety of subjects.

Table 2 shows enrollment rates for students aged 18-24 for full-time post-secondary students only and does not include students who may attend secondary school or who may work part-time and attend school part-time.

Table 2. Full-time Secondary Enrollment. (Source: Statistics CANADA)

PROVINCE	MALE	FEMALE
Newfoundland	15.4%	15.2%
Nova Scotia	18.0%	20.3%
Prince Edward Island	14.5%	17.3%
New Brunswick	12.2%	15.5%
Quebec	28.0%	27.3%
Ontario	24.5%	22.2%
Manitoba	18.7%	16.0%
Saskatchewan	16.0%	15.1%
Alberta	15.7%	16.0%
British Columbia	16.1%	14.9%
CANADA	22.3%	21.1%

Physics Education at the Secondary Level

In Ontario, as well as in the other provinces, physics is not taught as a separate subject until the senior grades 11/13. Science courses in grades 7-10 are described as a mosaic, dealing with biology, chemistry, physics, and environmental studies. In grades 9-13 there is a minimum of 110 hours required for a course over the ten-month school year, so students have at least three hours per week of class time on each subject, and in many cases there are daily periods. For grades 7-8 the minimum length of science courses is 80 hours. For a diploma at least two science courses are required, and most students have more. Science courses are also offered in elementary schools, the quality and quantity depending to some extent on local boards of education. In all provinces the study of science is mandatory until at least grade 8, but is an elective in the senior grades.

Table 3 shows enrollment by subject area in Ontario schools in 1985.

Table 3. Enrollment of Students by Subject Area at Secondary Level. (Source: Education Statistics, Ontario 1985)

	Intermediate (Gr. 9 & 10)			Senior (Gr. 11 & 12)			Senior (Gr. 12 & 13)		
	Male	Female	Total	Male	Female	Total	Male	Female	Total
English	150,989	139,314	290,303	126,883	119,144	246,027	20,765	22,541	43,306
Science	130,461	125,138	255,599	2,518	1,335	3,853	------	------	------
Biology	6,618	6,426	13,044	19,421	28,887	48,308	11,371	15,771	27,142
Chemistry	495	244	739	32,765	27,512	60,277	15,159	11,550	26,709
Physics	1,949	1,729	3,678	38,478	24,303	62,781	15,235	6,833	22,068

These statistics include English for comparison since almost all students take this subject, so it is an indication of total enrollment. Since the individual sciences are normally not offered as separate subjects before grade 11 (except in some special or private schools), enrollment in these at the intermediate level is not very meaningful; most of these students are probably taking a higher level course while nominally in grade 10, so the numbers could be added to the grades 11-12 data. There are a number of other subjects generally called science (e.g., environmental studies, applied science) or technological studies (e.g., electricity, materials, and processes, manufacturing) which are included in the published statistics, but not shown here because the numbers of students involved are small.

The total enrollment in physics in grades 11-12 is higher than in chemistry or biology. Male students predominate in physics and chemistry, while females predominate in biology. In grade 13 this trend is increased, with the limited numbers of female students choosing physics dropping this subject to third place overall.

Table 4 shows estimated science enrollment for 1983-84 by discipline and by province for the final year of high school. Large variations occur because a specific subject may be offered in grade 11 but not in grade 12. However, it can be observed that at least a third of all students do study physics in the graduating year. Table 5 shows full-time teacher qualifications by the highest degree.

Table 4. Estimated Science Enrollment in Canada. (Source: Science Education in Canada, Vol. I. 1985)

Province	Grade	Enrollment	Course	Students (%)
Newfoundland	12	8,930	Biology	56%
			Chemistry	18%
			Physics	30%
Nova Scotia	12	12,150	Biology	48%
			Chemistry	38%
			Physics	24%
Prince Edward Island	12	2,070	Biology	49%
			Chemistry	33%
			Physics	22%
New Brunswick	12	11,590	Biology	23%
			Chemistry	23%
			Physics	21%
Quebec	10,11	194,950	No data	
Ontario	13	72,040	Biology	46%
			Chemistry	46%
			Physics	39%
Manitoba	12	16,510	Biology	31%
			Chemistry	29%
			Physics	21%
Saskatchewan	12	14,610	Biology	67%
			Chemistry	48%
			Physics	41%
Alberta	12	33,840	Biology	61%
			Chemistry	50%
			Physics	30%
British Columbia	12	37,500	Biology	21%
			Chemistry	15%
			Physics	9%

Table 5. Teacher Qualifications by Highest Degree. (Source: Education Statistics on Ontario for 1985)

	Elementary		Secondary	
	Male	Female	Male	Female
Bachelor of Education	3,963	9,225	5,564	4,820
Other Bachelor	8,263	11,320	11,326	4,819
Master of Education	2,849	1,344	1,791	677
Other Master	315	337	1,947	642
Doctorate of Education	4	4	14	2
Other Doctorate	14	14	86	27
No Degree	2,203	14,867	3,037	600
Not Reported	45	41	29	17
Totals	17,656	37,152	23,794	11,604

To focus on teachers of courses specifically labeled physics, Table 6 shows the degree qualifications of physics teachers in secondary schools in Ontario in 1985-86.

Table 6. Physics Teacher Qualifications. (Source: Education Statistics on Ontario for 1985)

	Full-time	Part-time	Total
Bachelors	698	56	754
Masters	142	11	153
Doctorates	17	1	18
No Degree	2	1	3
Not Reported	2	0	2
Total Teachers of Physics	861	69	930
Total Teachers	35,398	4,939	40,377

These figures give degree qualifications, not qualifications for teaching physics. While there are no specific requirements, it is estimated that in Ontario of those teaching physics at the senior level, about two thirds have good backgrounds for teaching the subject, i.e., several university courses in physics and mathematics. Many teachers of physics also teach other subjects.

By 1975 in Ontario anyone entering the teaching profession, at both the elementary and secondary levels, was expected to have an acceptable university degree.

Preparation of Secondary School Teachers

Across Canada there are 40 institutions providing pre-service training (undergraduate degrees) of elementary and secondary teachers. In the past a university degree was not required of all teachers, and there were many separate teachers colleges, but now all are phased out or associated with universities as faculties of education. All pre-service programs include three components: academic courses (including some science courses if science concentration is elected), professional courses in educational foundations, and practical experience in classrooms. Some institutions offer "concurrent" or "integrated" programs, lasting three to five years, in which general university undergraduate work is combined with professional preparation. Others offer "after-degree" or "consecutive" one- or two-year programs in which a Bachelor of Education is completed after a Bachelor of Arts or Science.

To acquire information concerning the wide variety of programs offered, Connelly, Crocker, and Kass [authors of Science Education in Canada (1985)] surveyed 38 of the 40 institutions. Table 7 gives estimated teacher pre-service enrollment, with percentages in integrated and in after-degree programs, and also estimates of science enrollment for those planning to teach at the secondary level. The estimated figures in the second column are the total pre-service enrollment in the 1984-85 academic year, i.e., all student teachers, regardless of the year in which they were enrolled. The 3rd and 4th columns show the wide variation between provinces concerning the route followed; in only two provinces are the majority of students following the "after-degree route."

The 5th column gives an estimate of the total number of students who are preparing to teach science at the secondary level, with a breakdown into specific sciences by percentage in the following columns; the final column includes general and environmental science and a few earth science and geology students.

Respondees to the survey were queried about science enrollment in light of teacher demand, and the consensus seemed to be that biology is overenrolled while chemistry and physics are underenrolled. Table 7 demonstrates that physics is certainly not the preferred subject for aspiring teachers!

Table 7. Survey of Teacher Pre-service Enrollment.

Province	Total Pre-service TP	Integrated TP(%)	After Degree TP(%)	Total Science TS	Biology TS(%)	Chemistry TS(%)	Physics TS(%)	Other TS(%)
British Columbia	2,400	70	30	88	51	21	11	17
Alberta	4.650	87	13	406	54	19		27
Saskatchewan	2,450	93	7	104	51	24	18	7
Manitoba	2,170	93	7	100	52	16	8	24
Ontario	4,320	26	74	324	49	15	7	29
Quebec	5,270	?	?	266	51	31	18	--
New Brunswick	1,125	91	9	35	74	11	3	12
Prince Edward Island	50	38	62	2	100	--	--	--
Nova Scotia	740	63	37	24	54	21	4	21
Newfoundland	1,210	84	16	120	53	8	7	32
Total	24,385	72	28	1,323				

Physics Education at the University Level

Canadian universities in general offer a high quality education in physics. The system is very similar to that of the United States, in particular, in the institutions which provide instruction in English. In the French language institutions there are some differences, but in fundamental terms these differences are small.

Considered a fundamental subject, the basic undergraduate physics degree is the Bachelor of Science (BS). Many Canadian institutions also offer a large number of cross-disciplinary or inter-disciplinary degrees involving other departments. In fact, many universities offer programs in engineering-physics. In some cases faculty members in the physics departments hold joint appointments with other departments in the pure or applied sciences.

As an example of the English language institutions, some of the courses and programs offered at the University of Toronto will be discussed.

The University of Toronto provides several choices or types of programs to the undergraduate student in addition to the major area of physics. "Specialist" undergraduate programs in astronomy and physics, biology and physics, chemical physics, computer science and physics, geology and physics, and mathematics and physics are listed among regular options in the physics department. The Department of Physics has about 60 faculty members at the three professorial levels.

The introductory physics courses offered in the department include:

1) Basic Physics (PHY110Y) for students not intending to pursue further work in physics (typical textbook used is Mulligan, Introductory College Physics);

2) Mechanics, Waves, and Matter (PHY130Y)--this course is at the level of Halliday and Resnick, Fundamentals of Physics and may be considered as the pure physics entry to the Major Programme in Physics;

3) The Forces and Phenomena of Physics, the first course offered in the Physics Specialist Programme--the contents are similar to the previous course but at a more advanced level (Feynman Lectures on Physics and Halliday and Resnick, Fundamentals of Physics);

4) Physics for the Life Sciences I, for students proposing life science programs. Contents include vibration and waves, sound hearing, echolocation and ultrasound, optics of vision, mechanics, atomic and molecular physics, and nuclear physics (typical textbook used is Kane and Sternheim, Physics).

All the students enrolled in the courses above take concurrently an introductory course in experimentation, starting with a selected experiment which each pair of students is obliged to complete, but from there on offering choices. Emphasis in the laboratory is on the general principles of experimentation, planning, use of instruments, error estimation, data analysis, and comparison with theory.

The students in the pure physics programs (regular major or specialist) can continue on to take courses in physics during their second year after completion of the mathematics requirements. These courses include: Electromagnetism, Waves and Optics at the level of Weidner and Sells Elementary Classical Physics; Practical Physics (2nd-year laboratory course); followed by courses in Electromagnetism (Level: Purcell Electricity and Magnetism); Statistical Physics (Kittel and Kroemer Thermal Physics); Introduction to Theoretical Physics, and Introductory Quantum Mechanics.

Other courses at a more advanced level may be taken in consultation with the department staff advisers. The level and variety of courses offer excellent possibilities for the undergraduate and graduate student.

Undergraduate students in the life sciences or other specialist areas such as geophysics can select courses in their speciality such as Earth and Atomospheric Physics, Physics for the Life Sciences II, Radiation in Planetary Atmospheres, The Physics of Medical Imaging, etc.

Students enrolled in advanced physics courses are invited to attend the Thursday afternoon department colloquia.

In pure physics, the University of Toronto has awarded 200 undergraduate degrees during the five-year period 1981-86. Over the same period, there were 200 masters and 120 doctoral degrees. The 1985 graduate enrollment in physics was 79 at the masters level and 113 at the doctoral level. The average time to complete a masters degree is 1.2 years and the PhD degree is 4 years.

Table 8 shows enrollment in physics for Canada as a whole for 1985-86.

Table 8. University Enrollment in Physics in Canada 1985-86. (Source: Statics Canada)

Undergraduate			Graduate		
Male	Female	Total	Male	Female	Total
2700	431	3131	1000	101	1101

The number of physics degrees granted by universities in Canada in 1985 by qualifications and by sex are shown in Table 9.

Table 9. Physics Degrees Granted in Canada, 1985.

Bachelors			Masters			PhDs		
Male	Female	Total	Male	Female	Total	Male	Female	Total
477	87	564	159	12	171	81	8	89

Of those completing the PhD, about half were expecting to continue on a postdoctoral or research fellowship.

Table 10 contains the number of university faculty teaching physics in 1985-86, by highest degree and by sex, excluding the province of Quebec.

Table 10. University Faculty Teaching Physics in 1985-86.

Highest Degree	Male	Female	Total
PhD	690	12	702
Masters	47	3	50
Bachelors	10	1	11
			763

As an example of the French language universities, the physics or physics-related programs of the University of Quebec will be considered, even though the largest French language university in Canada is the University of Montreal.

The "Université du Québec" (University of Quebec) was founded in 1968. The organization of the university is very different from other Canadian institutions. The traditional format of faculties and schools has been replaced by a structure composed of three elements: departments, modules, and research centers. The module is responsible for administering the first degree programs (premier cycle), while departments and research centers (higher degrees) are respectively responsible for teaching and research in any given discipline.

For admission, students must be in possession of the "diplóme d´etudes collégiates" (DEC) granted from the collèges d´enseignement général et professional (Community Colleges in Quebec) or its equivalent. These colleges are under the jurisdiction of the Quebec Education Department. In addition, students must satisfy specific course requirements. Applicants in physics must have completed the basic courses in mathematics, physics, and chemistry as described in the University Catalogue. These courses, in content, are similar to those offered by the English language universities during the first two years.

The first degree (premier cycle) takes about six semesters (three years to complete). In physics the first degree offered is the Bachelor of Science, with options also in teaching, geophysics, biophysics, physics, and other cross-disciplinary degrees. The undergraduate program in physics is oriented toward atmospheric physics.

Higher degree programs are also offered in the University of Quebec. The Master of Science (deuxieme cycle) requires advanced courses, written and/or oral examination, and thesis. It lasts about one and a half years. Other MS degrees related to physics include atmosphere science and energy science.

The PhD program (troisiéme cycle) is offered in biophysics and energy science. It requires a minimum of three semesters after completion of the Master's program. Students must complete some advanced courses of study, written and oral exams, and a thesis.

Research is carried out in the research institutions and constituent universities which are part of the University of Quebec's system.

Typical courses in physics offered at the University of Quebec include:

PHY 1110 and PHY 1210 - Méchanique Classique I, II (Classical Mechanics I and IIO
PHY 1180 - Optique (Optics)
PHY 1216 - Laboratoire d'électricité (Electricity Laboratory)
PHY 2220 - Électromagnéstime (Electromagnetism)
PHY 3412 and PHY 4420 - Physique Moderne I, II (Modern Physics I, II)
PHY 3121 - Physique des Ondes (Physics of Waves)
PHY 4120 - Méchanique des Fluides (Mechanics of Fluids)
PHY 5035 - Physique Expérimentale (Experimental Physics)
PHY 4640 and PHY 6644 - Physique de la basse atmosphére I, II (Atmosphere Physics I, II)

Efforts to Improve Physics Education

It is almost impossible to select specific projects for the improvement of physics education in Canada. The highly decentralized system of instruction places the responsibility of the educational system on the provinces and the universities enjoy full automony. However, the reader may review the situation of physics education at the secondary and tertiary levels in this country and will find that, in general, the faculty in the universities and teachers at secondary level have adequate credentials to fulfill their work properly.

Tables 5, 6, and 7 show that even at the elementary and secondary levels, many teachers are in possession of advanced degrees. Moreover, the quality of the universities and technological schools is excellent and these institutions continue to offer solid programs in physics and related areas.

It is interesting to notice also that many institutions offer cross-disciplinary degrees in the sciences at undergraduate levels. Besides, the traditional close relations between Canada and the United States have been beneficial for both countries. There are good relationships among scientists of both countries and many Canadians are or were participants in projects in the United States, Europe, etc.

The Professional Physicist

Information about the career profiles of professional physicists in Canada was not readily available during the preparation of this report. However, it is probably reasonable to suggest that the pattern is very similar to that in the United States except for the participation of Canadian physicists in industry. Most Canadian physicists find employment in universities or government laboratories, with a limited number working in industry; this work is likely to be in development or applied research, as very few Canadian industries have laboratories doing pure research. While the majority of physicists belong to the Canadian Association of Physicists, most are also members of the appropriate division of the American Physical Society and attend conferences on their research areas in the United States.

CHILE

General Information about the Country

The Republic of Chile has a surface area of approximately 756,626 km^2 or about 470,246 square miles. This area excludes the Chilean Antarctic Territory, portions of which are disputed with the United Kingdom and Argentina. Chile is a very long, narrow country (about 2600 miles in length) facing the Pacific Ocean and extending from Peru and Bolivia in the north to Cape Horn in the far south. Several small islands including Isla de Pascua are part of Chile. The country is separated from Argentina to the east by the high Andes mountains. The climate is ifluenced by the mountains and the cold Humboldt Current. Rainfall varies between the desert in the north and the rainy south.

Chile was divided into 25 provinces before 1975. The new administrative system has divided this country into 12 regions and a metropolitan area where the capital, Santiago, is located. The 13 regions are subdivided into 50 new provinces and the metropolitan area of Santiago. The official language is Spanish.

The population, according to official estimates in 1986, was 12,271,173. The age breakdown for the population (1984) indicated that approximately 31.4% was under the age of 15; 29% between 15-29; 19.4% between 30-44; 11.9% in the age bracket 45-59; 6.3% was between 60-74; and 1.9% was 75 and over.

The ethnic composition (1980) of the population was 92% mestizo (mainly European descendants), 6% Indian (mostly Mapuche), and others 2%.

Illiteracy is very low in Chile compared to other countries in the Western Hemisphere. The data oftained for 1983 indicates that 95.6% of the total population over age 12 was literate. This rate might be even higher at present.

Exports of copper, both processed and unprocessed, provide more than 50% of Chile's total earnings of foreign exchange. The reserves of copper ore are estimated to represent 23% of the world's proven resources and are mainly concentrated in the mines of Chuquicamata and El Teniente. Gold metal and concentrates account for 5% of export revenues in 1985. Other minerals of economic importance are silver, iron ore (for domestic consumption and export), molybdenum, manganese, lead zinc, coal, etc. Chile has the largest known reserves of lithium.

Petroleum and natural gas are found in the south of Chile but the production is not enough to meet domestic needs. Chileans hope to satisfy national oil consumption by the beginning of the 21st century with the discovery of large new deposits in the Magellan Straits.

Chile has great agricultural potential, but according to well-informed observers, land use is inefficient. The agricultural sector has suffered serious setbacks since the early 70s due to drastic changes in the governments. Agriculture production is improving but still there are serious problems with cheaper imports of certain products. The output of the agricultural sector expanded by 7.9% in 1985.

Fishing also has great potential for Chile, and exports accounted for 12% of foreign exchange earnings. Manufacturing is important for Chile, but it faces very strong foreign competition. Tourism is another source of income for this country. Chile offers many attractions for tourists including ski resorts in the Andes, fine beaches, lakes, and rivers. There are also plenty of opportunities for fishing and hunting in the southern part of Chile (Archipielago) and Isla de Pascua.

In spite of the great potentials of this nation, Chileans are very concerned about the economic and political situation in their country.

The Educational System in Chile

The educational system in Chile is comprised of four levels: A) "Nivel Pre-Básico" (pre-primary level), B) "Nivel Básico" (primary level, C) "Nivel Medio" (secondary level), and D) "Nivel Superior" (higher education level).

A) "Nivel Pre-Básico" (Pre-primary level)

Pre-primary schooling or early childhood education is widely available for all children up to the age of six. The majority of these schools are in urban areas. The best of them are either private or sponsored by some state corporations or industries for the children of their employees. This level is not compulsory.

B) "Nivel Básico" (Primary Level)

Primary education is free at the state schools and compulsory for children in the age range 6-13 or 14. This level offers three different modalities:

i) "Educación General" (General Education) which is offered for eight years beginning at the age of six or seven. It is subdivided into two cycles, the first cycle extending from grades first through fourth and the second cycle comprising grades fifth through eighth.

The school curriculum includes reading and writing, mathematics, some simple science, geography, history, social sciences, music, arts, and physical education. A foreign language (English or French), at least in theory, is also included.

Children who complete this level receive a primary school certificate.

ii) "Educación Especial" (Special Education) which is offered for children with some disabilities and includes five years of basic education.

iii) "Educación de Adultos" (Adult Education). The adult education program offers three cycles of one year each of basic education. This program or system was implemented as a national campaign against illiteracy. According to well-informed observers, it has been very effective in reducing the rate of illiteracy from 11% in 1970 to about 5.6% in 1983.

C) "Nivel Medio" (Secondary School)

Secondary education normally begins when children are 14 years of age. It is divided into two categories: i) the humanities-science program and ii) the technical-professional program.

i) The humanities-science program lasts for four years. The emphasis is on general education and possible entrance to higher education (university). After completion of the courses of study, the students receive the diploma of "Licencia Media" (high school). The schools which provide humanistic-scientific education are known as "liceos."

ii) The technical-professional program is intended to be less academic-oriented and lasts up to six years. It is designed to meet the requirements of specialist training. It includes specialization in commercial, agricultural, industrial, and special services and techniques. After completion of the technical-professional program the students receive the diploma of Técnico de Nivel Medio (technician middle level). The title is also equivalent to that of "Licencia Media" (high school).

The two categories have a common program for the first two years of study.

D) "Educación Superior" (Higher Education Level)

The higher education level in Chile is divided into two modalities or sub-systems: i) "Nivel Universitario" (University Level), and ii) "Nivel no Universitario" (Non-University Level).

There are three types of institutions offering instruction in the higher education or tertiary level: "universidades" (universities), "institutos profesionales superiores" (professional institutes), and "Centros de formación técnica" (centers for technical preparation). The last two types of institutions are considered non-universities.

Twenty-four of these institutions of higher education, both public and private, are funded or subsidized by the state. They are members of the "Consejo de Rectores" (Chancellor's Council) which takes care of university coordination. After the University Law of 1981, the government appoints rectors and vice-rectors. Several private institutions have been established, encouraged by this law. Most of the information included in this report, however, is related to the institutions which are members of the "Consejo de Rectores."

The requirement for admission to the higher education level is the "Licencia de Educación Media" (Secondary School Diploma) and an Entrance Examination (Prueba de Aptitud Académica). Candidates for admission to the universities are usually also required to take an additional Test of Specific Knowledge. These factors are taken into account for acceptance to the universities.

The undergraduate degrees offered by the universities vary in length with a five-year degree program known as "Licenciado" as the norm.

Many of the Chilean universities offer traditional professional degrees in engineering, medicine, law, etc. Some of the universities also offer graduate degrees at the "Magister" (Master's Degree) and Doctoral (PhD) levels. It is worth mentioning that many of the Chilean universities have residential facilities for the students, which is not common in many of the Spanish-speaking countries.

The administration of the educational system in Chile is being decentralized. At the national level, the Ministry of Education is the authority that defines the educational policies with the Under-Secretary of Education in charge of the implementation of these policies. The "Dirección General de Educación" (Directorate General of Education) prepares and proposes the technical and pedagogical norms for the application of the educational policies. The "Superintendencia de Educación" (Office of the Superintendent of Education) is concerned with planning by the sectors.

After 1974, "Secretarías Regionales del Ministerio de Educación" (Regional Secretariat of the Ministry of Education) were established in each of the regions of Chile as an attempt to decentralize the educational system. The regional authorities are in charge of planning, supervising, and evaluating the educational system in each region. Moreover, at the provincial level, the "Secretarías Provinciales de Educación" (Provincial Directorate of Education) are autonomous and in charge of enforcing the tasks and rules established by the Regional Secretary.

The municipalities, since 1980, became responsible for the primary and secondary schools. This control extends to the teachers.

Table 1 includes some data about the educational system in Chile.

Table 1. Information on the Educational System in Chile. (Source: Encyclopedia Britanica, Nations of the World, 1984).

Level of Education	No. of Schools	No. of Teachers	No. of Students
Primary (age 6-13)	8,862	6,274	2,092,069
Secondary (age 14-17)	1,401	N/A	581,243
Vocational	369	N/A	129,817
Higher (Terciary)	24	10,372	126,197

Physics Education at the Secondary Level

During the first and second year of the secondary level, which are common for the humanities-science program and the technical-professional program, students receive a course in natural sciences. It includes topics or units in physics, chemistry, and biology. In some cases, this course is taught by one teacher in the natural sciences with preparation in physics, chemistry, or biology. It is possible, however, to find three teachers, one from each of the disciplines, sharing the teaching responsibilities for this course. Teachers at the secondary level are known as "profesores de estado."

Physics, as a discipline, is offered during the third and fourth year of the humanities-science program. This discipline is elective, and students can choose it among other subjects, including chemistry. There are no official statistics about the number of students who select physics because this system of electives has been used for only a few years.

Table 2 shows some official data about physics teaching in the secondary level. There are some discrepancies with the statistics shown in Table 1.

Table 2. Secondary Level Statistics. (Sources: Educación 1984, Inst. Nacional de Estadistica; Centro de Perfeccionamiento e Investigaciones Pedagogicas, Chile 1986).

Year	No. of Students	Total No. of Teachers (with or without a degree)	Teachers with a degree in Physics
1980	1,169,484	30,850	--------
1985	667,797	37,335	554

The total number of periods of instruction per week in the humanities-science program is 30 (each period lasting 45 minutes). In addition, there are two extra periods per week of religion which is elective.

During the first and second year, students receive five periods per week of instruction in sciences (natural sciences). Physics is offered three periods per week during the third and fourth years for those students who choose this subject as an elective. The level of these courses is comparable to the PSSC textbooks and/or the books in physics for secondary level authored by Dr. Alberto Maiztegui.

Most of the physics teachers at the secondary level are in possession of a degree in pedagogy (Pedagogo) with some preparation in physics. There are very few teachers at this level with a Master's Degree (Magister) in physics and probably there are no teachers in possession of a Doctor's degree. The Ministry of Education has no statistics available on this matter. It is worth mentioning, however, that the number of teachers enrolled in graduate programs is increasing.

Physics teachers at the secondary level normally have to work in more than one school to complete the 36 periods of instruction per week required by law (full-time teaching). Evidently, with physics being an elective subject, the school must have a large enrollment for there to be a sufficient number of groups or class-periods in physics to justify a full-time position in this area.

Preparation of Physics Teachers for the Secondary Level

The preparation of secondary school teachers (profesor de estado) has been taking place in the universities for several years. Recently, this responsibility is being shifted to the "institutos profesionales" (professional institutes). However, most of the universities continue offering a degree for secondary school teachers (pedagogy) with specialization in physics, natural sciences, physics and chemistry, physics and statistics, and physics and mathematics.

Table 3 on the following page shows the enrollment and number of graduates in some of the institutions (unversities and professional institutes) affiliated with the "Consejo de Rectores" (Chancellor's Council).

There are many programs or curricula for the degree of secondary school teachers. In particular, the number of credit hours dedicated to the major area of concentration and the pedagogic or educational preparation vary according to the institution offering the degree. Some institutions dedicate about 50% of their programs to the major area (physics, chemistry, biology, etc.). In others this percentage can go as high as 80% with only 20% dedicated to the pedagogic preparation of the future teacher.

Table 3. Enrollment and Graduates at Some Institutions of Higher Education Affiliated with the Consejo de Rectores. (Sources: *Educación 1984*. Inst. Nacional de Estadística Chile and *Anugario Estadístico*, Consejo de Rectores Universidades Chilenas 1986.) Figures marked with an asterisk indicate that no students were admitted as freshmen in 1986.

Institution and Location	Number of Students 1984	Number of Students 1985	Degrees Granted 1985
Universidad Católica de Valparaiso	62	48	5
Universidad Metropolitana Santiago	146	154	11
Universidad de Playa Ancha Valparaiso	69	65	1
Pontificia Universidad Católica (Campus Talcahuano)	53	18*	5
Universidad de la Serena La Serena	94	209	9
Universidad de la Frontera Temuco	Incomplete Information	151	6
Universidad de Tarapacá Arica	40	27*	5
Universidad de Antofagasta Antofagasta	28	53*	8
Universidad de Talca Talca	103	84*	22
Instituto Profesional de Chillán	106	116*	11
Universidad de Magallanes Punta Arenas	31	28*	5
Universidad de Santiago de Chile	161	139*	33
Pontificia Univ. Católica Santiago	132	50*	8
Pontificia Univ. Católica Temuco	139	17*	8
Universidad de Atacama Copiapó	6	6*	3

Physics Education at the University Level in Chile

Physics is taught at the universities in Chile not only for students specializing in physics but also as service courses for careers in engineering, health sciences, education, etc. Table 4 shows some statistics about students enrolled in physics courses (1985).

Table 4. Number of Students Enrolled in Some Physics Courses in the Universities Associated with the Consejo de Rectores (1985) (Source: Consejo de Rectores Universidades Chilenas 1986).

Area	No. of Students
Education	30,921
Natural sciences and mathematics	5,498
Technological careers (engineering, etc.)	41,534
Health sciences	13,137
Total	127,486

The first undergraduate degree in physics granted by Chilean universities is known as "Licenciado." However, secondary school teachers in physics, physics mathematics, etc. are still prepared mainly in the universities. As an example, the programs for secondary school teachers and "Licenciados" in physics at the "Pontificia Universidad Católica de Santiago" will be presented. The reader should be aware that these programs vary according to the institution, region, etc.

The program for an undergraduate degree at this institution includes courses which are mandatory and vary according to the specialization selected. These types of courses are considered as the "currículo minimum" (minimum curriculum). In addition, the student must complete the "currículo complementario" (Complimentary curriculum) which includes courses in the specialization (major area) and courses in general education, one in each of five areas: sciences, humanities, theology, social sciences and economics, and physical education.

For the degree of "Profesor de Matemáticas y Fisica" (Teacher in Matnematics and Physics) the student will follow the guidelines established by the School of Education, but the physics courses are offered by the "Facultad de Fisica" (School of Physics).

The student, during the first five semesters, takes a group of courses that are common for those who intend to be secondary teachers in math and physics and for students interested in obtaining the degree of "Licenciado en Fisica" (undergraduate degree in physics). It takes about four or five years to complete each of these degrees.

1) Common Core

MAT 1110	Geometría I (Geometry I)
MAT 1120	Geometría II (Geometry IIO
MAT 1200	Algebra Lineal I (Linear Algebra I)
MAT 1490	Introducción al Calculo (Intro. to Calculus)
MAT 1500	Calculo I (Calculus I)
MAT 1510	Calculo II (Calculus II)
MAT 1520	Calculo III (Calculus III)
MAT 1530	Ecuaciones Diferenciales (Differential Equations)
EYP 1210	Introducción a la Probabilidad y Estadística (Intro. to Probability and Statistics)
IIC 1130	Computacion I (Computers)
FIZ 010	Fisica General I (General Physics I)
FIZ 020	Fisica General II (General Physics II)
FIZ 120	Calor y Termodinámica (Heat and Thermodynamics)
FIZ 130	Electricidad y Magnetismo (Electricity & Magnetism)
FIZ 140	Ondas, Optica y Fisica Moderna (Waves, Optics and Modern Physics)
FIZ 211	Mecánica Intermedia I (Intermediate Mechanics I)
FIZ 241	Fisica Cuantica (Quantum Physics)
FIZ 110	Mecánica (Mechanics)
	General Education courses as required.

2) Ciclo Básico Diferenciado (Basic Cycle, Specialty)

MAT 1130	Geometría III (Geometry III)
MAT 1280	Fundamentos de la Matemática (Foundations of Mathematics)
MAT 1540	Complementos de Analysis (Analysis)
MAT 2150	Algebra Abstracta (Abstract Algebra)

In addition the student will take the required courses listed in the "Facultad de Educación" (School of Education). The student should also show comprehension of a foreign language (English, French, or German).

Typical textbooks used in the physics courses are:

General Physics I, II, *General Physics* by F. Miller
Mechanics, *Newtonian Mechanics* by A.P. French
Heat and Thermodynamics, *Thermodynamics* by M.W. Zemanski
Electricity and Magnetism, *Fundamental University Physics* by Alonso-Finn
Waves, Optics, and Modern Physics, *Vibrations and Waves* by French
Optics by Welford
Modern Physics by French
Intermediate Mechanics, *Theoretical Mechanics* by Becker
Quantum Physics, *Quantum Physics* by S. Gasiorowicz.

Six laboratory sessions (one every 15 days) are required in each course.

"Licenciado" in Physics requirements:

Ciclo Diferenciado (Basic, Specialization)		*Book*
FIZ 212	Mecánica Intermedia II (Intermediate Mechanics II)	*Classical Mechanics* Goldstein
FIZ 231	Teoría Electromagnetica I (Electromagnetic Theory I)	*Foundations of Electromagnetic Theory*, Reitz and Milford
FIZ 251	Metódos de Fisica-Matematica I (Mathematical Methods in Physics)	*Elements of Complex Variables*, Pennisi

One elective

Ciclo Terminal (Terminal Cycle)

In addition, the student should complete the following courses:

FIZ 221	Mecánica Estadística (Statistical Mechanics)	*Statistical Mechanics*, McQuarrie
FIZ 232	Teoría Electromagnética II (Electromagnetic Theory II)	*Foundations of Electromagnetic Theory*, Reitz and Milford; *Optics*, Lipson and Lipson
FIZ 242	Fisica Cuantica II (Quantum PHysics II	*Quantum Physics*, Gasiorowicz
FIZ 252	Métodos de Fisica-Matemáticas II (Mathematical Methods II)	*Methods of Math-Physics*, Vol. I, Courant and Hilbert

Students who intend to receive the "Licenciado" in Physics must take the above courses after completion of the *Common Core*.

FIZ 301	Fisica Experimental (Experimental Physics	Laboratory Course (6 advanced experiments, minimum)
FIZ 441	Intro. a Fisica de Partículas (Intro. to Particle Physics)	*Introduction to High Energy Physics*, Perkins
FIZ 361	Intro. a Fisica de Sólidos (Solid State Physics)	*Intro. to Solid State Physics*, Kittel
FIZ 490	Práctica (Practicum)	Requires work in Exp. or Theoretical Physics.

Students, after completion of course work and report on FIZ 490, must take a graduation examination.

Table 5 shows some statistics related to the qualifications of the faculty in physics in the Chilean universities.

Table 5. Qualifications of the Physics Faculty in Chilean Institutions of Higher Education. (Source: Consejo de Rectores Universidades Chilenas 1986).

Institution and Location	Faculty w/advanced degree (Magister, Phd)	Faculty w/ professional degree	Faculty w/o professional degree
Universidad Católica Valparaiso	11	14	--
Universidad Metropolitana Santiago	1	24	--
Univ. de Playa Ancha Valparaiso	6	41	--
Univ. de Concepcion Concepcion	69	99	--
Pontificia Univ. Católica Talcahuano	21	86	--
Univ. de la Serena La Serena	19	84	1
Univ. de la Frontera	10	104	--
Univ. de Tarapacá Arica	19	101	--
Univ. de Antofagasta Antofagasta	31	38	--
Univ. de Talca Talca (Physics Dept.)	14	27	--
Instituto Profesional de Chillán Chillán (Physics Dept.)	13	26	--
Univ. de Magallanes Punta Arenas	15	78	--
Univ. de Santiago de Chile	149	483 Most of them hired by the hour (part-time)	1
Pontificia Univ. Católica Temuco	21	84	--
Univ. Austral de Chile Valdivia	43	68	--
Univ. del Norte Antofagasta	7	9	--
Pontificia Univ. Católica Santiago (School of Physics)	23	8	--

Graduate Programs in Physics

Table 6 shows some data about the universities in Chile offering Master's Degree (Magister) in Physics.

Table 6. Institutions Offering Master's Degree in Physics (Source: Consejo de Rectores de las Universidades Chilenas 1986).

Institution	Degree	Students Enrolled 1985	Graduates 1985
Universidad de Chile	Magister Ciencias Fisicas (Master Physical-Science)	18	2
Pontificia Universidad Católica	Magister Fisica (Master Physics)	8	2
Universidad Católica de Valparaíso	Magister Ciencias Fisicas (Master Physical-Sciences)	10	2
Univ. Técnica "Federico Santa Maria"	Magister Ciencias (Master in Sciences, major, Physics)	2	1
Univ. de Santiago	Magister Ciencias (Master in Sciences, specialty Physics)	8	-
Universidad Austral	Magister en Fisica (Master in Physics)	29	6

There are two institutions offering Doctor's Degrees in Physics. The enrollment is low, as indicated in Table 7.

Table 7. Universities Offering Doctor's Degrees in Chile.

University	Degree	Enrollment 1985	Graduates 1985
Univ. de Chile	Doctor en Ciencias (Doctor in Sciences, major in Physics)	4	1
Pontificia Universidad Católica	Doctor en Ciencias Exactas (Doctor in Pure Sciences, Major Physics)	2	0

Efforts to Improve Physics Education

The efforts to improve physics education in the past few years have been very sporadic. An example of one of these efforts is the graduate program offered by the Universidad Austral de Chile in Valdivia. This university offers courses in physics each January that are directed by Dr. Igor Saavedra. Students enrolled in the program could receive the degree of Magister (Master's Degree) upon completion of the course work and a thesis. There is a limited number of scholarships offered to both Chilean and foreign applicants.

Many well-informed observers consider that the professors and faculty involved in research work are very isolated. Teaching is very traditional in spite of the mostly well-prepared faculty in the institutions of higher education.

The Professional Physicist

The activities of physicists in Chile are mainly academic with teaching being the most important component. Research is limited and mainly done on a personal basis.

The number of physicists working in industry is, at best, limited to two or three. There is no information available about physics work conducted at research institutions.

COLOMBIA

General Information about the Country

Colombia is the only South American country with borders both on the Atlantic and Pacific Oceans. To the west, Colombia faces the Pacific Ocean; to the northwest, it has borders with Panama; to the north, it faces the Atlantic Ocean (the Carribean); to the east, it has borders with Veneuzuela and Brazil; and in the south, it has borders with Ecuador and Peru and on the southeast with Brazil. The territory of Colombia includes also the Islands of San Andres and Providencia.

Its surface area is approximately 1,138,914 km^2 or 439,735 square miles, with a population, according to the 1985 census, of 27,827,932. The capital is Bogotá.

Colombia is divided in 23 "departamentos," 4 "intendencias," and 4 "comisarías." It can be considered a very "young" country because 67.22% of the population is below 30 years of age and only 11.78% is above 50 years of age. Table 1 indicates the distribution of the population by age.

Table 1. Distribution of the Population by Age.

Age	Number	%	Age	Number	%
1	62,050	2.20	45 - 49	1,044,109	3.75
1 - 4	2,757,872	9.91	50 - 54	919,946	3.30
5 - 9	3,444,848	12.37	55 - 59	694,379	2.49
10 - 14	3,226,267	11.59	60 - 64	578,699	2.08
15 - 19	3,254,871	11.69	65 - 69	399,742	1.44
20 - 24	3,000,600	10.78	70 - 74	305,301	1.10
25 - 29	2,417,131	8.68	75 - 79	184,552	0.66
30 - 34	1,907,275	6.85	80 - 84	112,523	0.40
35 - 39	1,664,696	5.98	85 - 89	54,169	0.19
40 - 44	1,224,524	4.40	90 +	34,378	0.12
			Total	27,837,932	99.98

The population growth has been decreasing since 1973 when it was estimated to be very high. At present the population growth is about 1.3%.

Inflation is relatively low (20 to 30%) compared to most of the Latin American countries.

Colombians consider that illiteracy is still high (12.03% in 1985), but it has decreased from 17.7% in 1973. During the past few years the government developed relatively massive campaigns to reduce illiteracy and programs to improve the cultural level of the population, but their positive effects are not too evident according to the 1985 census. The lowest percentage of illiteracy is among the population that is 12 to 24 years old. Table 2 shows some specific data on illiteracy by age.

Table 2. Data on Illiteracy by Age.

Age	Population 5 years old and above (%)	Illiteracy (%)
5 - 6	6.06	-----
7 - 11	13.32	25.26
12 - 17	16.00	6.74
18 - 24	17.37	6.24
25 - 34	17.69	8.19
35 - 44	11.85	13.25
45 - 59	10.90	20.82
60 +	6.80	31.27
Subtotal 10+	85.84	12.03

The educational level of the population by age is indicated in Tables 3a, 3b, and 3c. It should be mentioned that the total population in this data was taken as 24,468,410.

Table 3a. Educational Level of the Population (Primary).

Age	Population (%)	Without Education	Primary School		
			Total	Complete	Incomplete
5 - 7	6.06	72.44	12.05	---	11.72
7 - 11	13.32	23.80	70.10	2.93	66.67
12 - 17	16.00	6.00	57.19	19.63	37.06
18 - 24	17.37	5.76	37.31	15.95	21.01
25 - 34	17.69	7.86	42.79	16.73	25.66
35 - 44	11.85	12.91	53.42	18.48	34.51
45 - 59	10.90	20.37	56.61	18.99	37.16
60 +	6.80	30.59	52.77	18.09	34.12
Subt. 10+	85.84	11.44	50.77	17.16	33.17
Total	100.0	16.7	49.4	14.7	34.2

Table 3b. Educational Level of the Population (Secondary).

Age	Population (%)	Without Education	Total	Secondary School Complete	Secondary School Incomplete
12 - 17	16.00		34.88	1.56	32.88
18 - 24	17.37		48.47	13.82	33.74
25 - 34	17.69		36.97	13.00	23.18
35 - 44	11.85		24.39	7.68	16.20
45 - 59	10.90		16.70	5.05	11.28
60 +	6.80		11.03	3.53	7.21
Subt. 10+	85.84		30.41	7.75	22.11
Total	100.0		26.1	6.6	19.0

Table 3c. Educational Level of the Population (Higher Education).

Age	Population (%)	Without Education	Total	0-3 years	4+ years
18 - 24	17.37		6.74	4.84	1.84
25 - 34	17.69		10.63	3.79	6.61
35 - 44	11.85		7.00	1.77	5.06
45 - 59	10.90		3.49	0.83	2.57
60 +	6.80		1.76	0.44	1.32
Subt. 10+	85.84		5.13	2.14	2.87
Total	100.0		4.4	1.8	2.5

The Educational System in Colombia

The educational system in this country was divided in the past in the following levels:

a) Pre-School Level.
b) Primary School Level, with a duration of 5 years.
c) Secondary School Level (6 years). The students at this level had some options.
d) Higher Education Level.

During the past few years, a new educational system is being developed and implemented (see Fig. 1). This new system includes:

a) Pre-School Level, for children 4 to 6 years old (two or three years of pre-primary school).

b) General Basic Education, dedicated to children 7 to 15 years old (grades one through nine). This level includes primary education and general secondary education.

c) Diversified Education, lasts two years and will include grades 10 and 11 (students 16 and 17 years old).

d) Higher Education or Post-Secondary, the duration of this cycle varies. Some students can select technological programs (3 years) or attend the regular university system (4 to 6 years of undergraduate education).

The curriculum and programs for the first seven years of basic general education have been completed and published by the Ministry of Education (Ministerio de Educación Nacional).

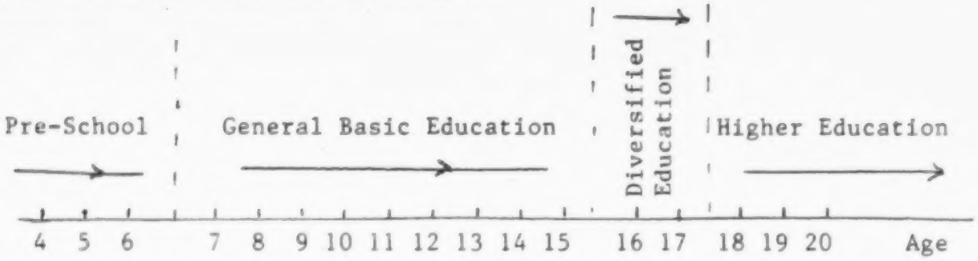


Fig. 1. New educational system being implemented in Colombia.

Tables 4 and 5 show the evolution in the enrollment of students at the different levels between 1978-83 according to the data provided by the Ministry of Education.

Table 4. Enrollment of Students at Different Levels of the Educational System.

Year	Total	Pre-School	Primary	Secondary	Higher Education
1978	6,142,000	137,000	4,119,000	1,634,000	254,000
1983	6,521,000	243,000	4,066,000	1,846,000	366,000

Table 5. Distribution of Enrollment (Percentage) among State-Supported and Private Institutions.

	Pre-School		Primary Level		Secondary		Higher Education	
Year	State	Private	State	Private	State	Private	State	Private
1978	33.2	66.8	85.5	14.5	56.5	43.5	47.6	52.4
1983	38.0	62.0	86.2	13.8	58.7	41.3	38.8	61.2

It is interesting to notice from the tables that there is a decrease in enrollment at the primary school level, but it is due to a decrease in the population growth since 1978. However, the percentage of students attending primary school has increased.

There are several options for the students in the diversified level of education, namely:

a) "Bachillerato académico" (academic), where the emphasis could be placed in the sciences or the humanities.
b) "Bachillerato pedagógico" (preparation for primary school teachers).
c) "Bachillerato en Promoción Social" (social sciences).
d) "Bachillerato Comercial" (business).
e) "Bachillerato Industrial" (technology and industry, vocational).
f) "Bachillerato Agropecuario" (agriculture).

For many years, some of these options have been available in certain secondary schools.

Fifteen years ago, the national government established the "Institutos de Educación Media Diversificada" (institutes of diversified middle-education). These centers offer all the options indicated above.

At the beginning of this decade, the Colombian government established the "Centros Auxiliares de Servicios Docentes" or CASD (auxiliary centers for educational services). These centers offer the facilities for all the specialties or options in the diversified level, including another option in the arts. These centers offer their services to secondary schools (state schools and some private schools) that do not have the facilities and laboratories for the diversified level.

In spite of all the options available to the students, the academic options still have 75% of the total enrollment, the business option 12%, and lower percentages are found in the other options or specialties.

The teaching personnel at the different levels is shown in Table 6.

Table 6. Teaching Personnel at Different Levels (1983).

		Official or State Institutions		Private Institutions	
Level	No. of Teachers	Number	%	Number	%
Pre-School	9,156	3,674	40.13	5,482	59.87
Primary	132,210	112,794	85.31	19,416	14.69
Secondary	91,646	54,833	59.83	36,813	40.17
Higher-Educ.	39,238	16,724	42.62	22,514	57.38
Total	272,250	188,025	69.06	84,225	30.94

From the data and tables above it should be noted that private education plays a very important role in the educational system in Colombia. Moreover, the statistics related to the number of teachers in the state and private sector might not be accurate. Many schools and universities from the private sector used professors from the state institutions as part-time teachers. Their salaries are very low in the private sector but it is a way for full-time professors or teachers from the state institutions to increase income. Some Colombians feel that it is a hidden subsidy of the government to the private sector. It is very difficult to quantify the magnitude of this problem.

Physics Education in the Primary and Secondary Level

In Colombia the curricula and course contents in primary and secondary education are regulated or established by the Ministry of Education (Ministerio de Educación Nacional). Using the old traditional classification of the different educational levels, which is being changed, physics does not appear as a regular discipline either in the primarl school (grades first through fifth) or the basic secondary level (grades sixth through ninth). During those years, students receive courses in natural sciences (ciencias naturales), including some with emphasis in biology in grades seven through nine.

In the new curricula being implemented, there are many physics topics included in some courses from grades first through sixth. For instance, topics on the behavior of light, experiences with simple electrical circuits, discussions about motion, and some topics on astronomy are being included in the new curricula.

Physics as a separate discipline appears in the programs for grades ten and eleven of all the specialties or options of the diversified cycle. These courses are offered three hours per week except for the "Bachillarato Académico" (academic option) with emphasis in the sciences where physics is offered five hours per week (grades ten and eleven).

Physics teaching (topics in physics offered in grades one through nine) is in the hands of primary school teachers with a degree in "Bachillerato Pedagógico" (secondary school graduates) or "Licenciados" in biology and chemistry. Physics teaching in grades ten and eleven is mostly in the hands of professors with a "Licenciado" degree in mathematics and physics (university level). This personnel has been exposed to courses in physics, but still in many cases their comprehension of the basic concepts is not very good. This problem is the consequence of physics education at the university level. In many universities, the courses in physics are theoretical, with very little or no experimental component due to lack of equipment or laboratories and/or insufficient training of the university professors in experimental physics.

Based on the information available, the total number of students enrolled in secondary education is between 1.0 and 1.0 million. It is calculated that 300,000 should be taking courses in physics in grades ten and eleven (1986). The number of secondary school teachers was estimated at 92,000 (1983), with 14,000 to 15,000 teaching physics and mathematics

(Licenciados in Physics-Mathematics). The number of secondary schools in 1978 was 3,900 and in 1981 this number increased to 4,200. Thus, for 1986 it was estimated at 4,500 including both state and private secondary schools.

The growth of the educational system was slower during the period 1981-86 compared to the decade of the 70s. In fact, the dramatic growth of the higher education level of the 70s has decreased, and many Colombians consider that there is a stagnant period in the whole educational system in Colombia. Even the salaries of the secondary school teachers are paid late, due (apparently) to the enormous budget deficits. A typical example of the situation was indicated in the geographical region of the Valle del Cauca. In 1980 there were 4,264 secondary school teachers in state-supported schools, but in 1986 the number was down to 4,183. On the other hand in the private schools of the same region, there were 4,233 teachers and in 1986 the number went up to 4,458.

There is no data available at the national level about the preparation (degree) of the secondary school teachers in charge of the physics courses. The Ministry of Education keeps only statistics about the total number of secondary school teachers but does not divide them according to their area of preparation. However, some data was obtained in 1978 in the geographical areas of Valle del Cauca and the Atlantic Coast (Departamentos de Atlántico, Bolívar, Magdalena, and Sucre). According to this data, 70.4% of the secondary school teachers had a university degree. In the Atlantic Coast it was found that 83.3% were in possession of a university degree. These figures should be higher at present, because many universities have been offering programs to allow secondary school teachers to complete their university preparation.

At present there are laws that prohibit the appointment of secondary school teachers without the corresponding degree. In addition, the new teachers should be selected through competition (examination), to avoid any political interference in the appointment process. These laws are not always enforced, but there is no doubt that these efforts have been very positive in the selection process of secondary school teachers.

Physics Education at the University Level

With very few exceptions, the Colombian universities have been organized by academic departments since the late 50s and beginning of the 60s. The physics departments offer all the courses in physics required in any program or career in the universities. The preparation of the secondary school teachers follows this pattern. However, in Colombia there are no special institutions outside the universities for the preparation of secondary school teachers such as the teacher's training institutions existing in other countries.

The more developed universities in Colombia have faculties of sciences, and the physics departments are an integral part of these schools or faculties. The members of the physics department are in charge of teaching, research, and extensive courses in physics. The programs for "Licenciado en Educacion" (secondary school teacher degree) are under the supervision of the schools of education, but the course work in the major areas such as mathematics, physics, chemistry, and biology are offered in the corresponding departments of the faculty of sciences.

Some universities do not have the faculty of sciences and the physics departments might be under the schools of education or the schools of engineering. In some instances the existing physics departments are responding to a vice-chancellor or a dean. It should be clarified that the "Licenciado" degree is granted only by the schools of education for secondary school teachers.

The undergraduate studies in physics (physicist) were initiated in 1962 in the Universidad Nacional de Colombia (Bogotá), in 1966 in the Universidad del Valle (Cali), in 1967 in the Universidad de Antioquia (Medellín), in 1979 in the Universidad de los Andes, and in 1984 in the Universidad Industrial de Santander.

Tables 7, 8, and 9 show the number of professors in several institutions according to their highest degree and their load. The letters FT indicate full-time professors; PT indicates part-time, and PH is used for the professors hired only to teach certain numbers of hours or courses per week. These tables have been subdivided into two groups: (1) institutions offering only the degree of "Licenciado" and services to other careers, and (2) institutions offering the degrees of "Licenciado," the degree of Physicist (university professors) and graduate programs in physics.

Table 7. Number of Professors and Their Degrees in Some of the Colombian Universities (1980).

University		Licenciado	Físico	Magíster	Doctor or PhD	Other	Total
Amazonía	FT	--	2	-	-	-	-
Incca	FT	3	2	-	-	-	5
	PT	1	-	-	-	3	4
	PH	4	3	-	-	23	30
Javeriana	FT	-	4	2	-	-	6
	PT	-	1	-	-	-	1
	PH	2	8	-	-	1	11
Nariño	FT	4	2	1	1	2	10
	PH	2	-	-	-	4	6
Pamplona	FT	8	1	4	-	1	14
Pedagógica y Tec. de Col.	FT	12	2	4	2	2	22
	PH	3	-	-	-	-	3
Quindío	FT	7	4	1	-	5	17
	PH	10	-	-	-	-	10
Sucre	FT	-	1	-	-	-	1
	PH	1	-	-	-	-	1
Surcolombiana	FT	5	-	1	-	-	6
	PH	2	-	-	-	-	2
Subtotal	FT	39	18	13	3	10	81
	PT	1	1	-	-	3	5
	PH	24	11	-	-	28	63

Table 8. Number of Professors and Their Degrees in Some Colombian Universities (1980).

University		Licenciado	Fisico	Magister	Doctor or PhD	Other	Total
Antioquia	FT	1	28	20	5	-	44
	PH	-	4	-	-	-	4
Ind. Santan.		-	2	8	5	9	24
Nacional	FT	1	35	31	6	2	75
	PT	-	-	1	1	-	2
	PH	-	3	1	1	1	6
Tecn. Chocó	FT	8	1	1	-	-	10
	PH	1	-	-	-	1	2
Tecn. Magdal.	FT	3	-	1	1	4	9
Tecn. Pereira	FT	5	4	6	-	2	17
Valle	FT	-	12	12	5	-	29
Subtotal	FT	18	82	69	22	17	208
	PT	-	-	1	1	-	2
	PH	1	9	1	6	2	12
Totals Tables 7 & 8	FT	57	100	82	25	27	291
	PT	2	1	1	1	4	9
	PH	24	18	1	1	29	73

The tables indicate that between 1980-1986 the growth in the number of professors levelled off after a rapid increase during the 70s. In addition, the number of professors with advanced degrees (Masters and Phds) increased.

A comparison among the universities offering the degree of "Físico" with those offering only the degree of "Licenciado" shows that the first group has improved dramatically in the number of professors with a Doctor degree.

The tables also indicate that the number of professors hired on an hourly basis (teaching one or two courses) has increased. This situation is not ideal for the institutions of higher education. Many Colombians attribute it to the budget assigned to the universities, which hardly coveres inflation. In fact, the salaries of the full-time professors are declining and in the near future will force them to accept part-time positions in other institutions to supplement their income.

Table 9. Number of Professors and Their Degrees in Colombian Universities (1986).

University		Licenciado	Físico	Magíster	Doctor or PhD	Other	Total
Amazonía	FT	-	4	-	-	-	4
	PH	-	1	-	-	-	1
Incca	FT	5	1	1		3	10
	PH	3	9	1	-	11	24
Javeriana	FT	-	4	2	-	-	6
	PT	-	-	2	-	-	2
	PH	-	13	7	-	1	21
Nariño	FT	4	2	3	1	1	11
	PH	4	2	2	-	1	9
Pamplona	FT	6	1	7	-	1	15
	PT	-	2	1	1	1	2
	PH	-	5	1	-	-	6
Pedagógica y Tec. de Col.	FT	9	1	6	-	2	18
	PH	5	-	-	-	-	5
Quindío	FT	1	-	8	1	2	12
	PH	5	-	-	-	-	5
Sucre	FT	-	3	-	-	-	3
	PH	1	-	-	-	-	1
Surcolombia	FT	2	1	6	-	1	15
	PH	2	-	-	-	-	2
Tec. de Chocó	FT	10	2	2	-	1	15
	PT	-	-	-	-	1	1
	PH	2	-	-	-	1	3
Tec. Magdalen	FT	2	-	2	1	4	9
	PH	2	-	-	-	-	2
Tec. Pereira	FT	2	2	13	-	1	18
	PH	6	-	3	-	-	9
Subtotals	FT	41	21	50	3	15	130
	PT	0	2	2	0	1	5
	PH	30	30	14	0	14	88
Antioquia	FT	1	7	28	8	-	44
	PH	-	2	-	-	-	2
Ind. Santand.	FT	-	1	9	11	1	22
	PH	-	2	-	-	-	2
Nacional	FT	1	16	38	19	3	77
	PT	-	-	1	-	-	1
	PH	-	1	1	1	1	4
Valle	FT	-	9	14	8	-	31
	PT	-	5	1	-	-	6
	PH	-	5	-	-	-	5
Subtotals	FT	2	33	89	46	4	174
	PT	0	5	2	0	0	7
	PH	8	8	7	1	3	27

Table 9 continued on next page.

Table 9. (Continued from previous page).

University		Licen-ciado	Físico	Magíster	Doctor of PhD	Other	Total
	FT	43	54	139	49	19	304
TOTALS	PT	0	7	4	0	1	12
	PH	38	38	21	1	17	115

The Degree of "Licenciado" in Mathematics-Physics

These programs are normally granted by the schools of Education with most of the course work offered by the departments of physics for secondary school teachers. The requirements and options for the degree of Licenciado varies among the universities. In some of the institutions of higher education there is an option with a major area in mathematics and a minor in physics. Others offer only one option--mathematics-physics--and there are some that offer the "Licenciado" degree in mathematics and "Licenciado" degree in physics. Tables 10 and 11 show the enrollment and graduates for secondary school teaching in some Colombian institutions.

Table 10. Total Enrollment (Licenciados in Physics and Mathematics), 1981-1986.

University	1980	1981	1982	1983	1984	1985	1986
Amazonía	48	60	62	75	88	91	98
Nariño	-	158	171	170	182	180	185
Pamplona	137	136	122	116	105	-	-
Pedag. y Tech.	96	90	85	80	85	90	100
Quindío	30	35	30	20	20	-	-
Surcolombiana	129	99	126	132	142	153	155
Tecn. Chocó	124	112	121	112	146	136	131
Tecn. Magdalena	60	60	60	60	60	55	55
Tecn. Pereira	312	316	258	289	306	268	233
Del Valle	154	155	303	117	171	122	93
TOTALS	1.090	1.221	1.338	1.171	1.305	1.095	1.050
Index		100.0	109.6	95.9	106.9	89.7	86.0

Table 11. Graduates in Physics and Mathematics (1981-1986).

University	1980	1981	1982	1983	1984	1985	1986
Amazonía	9	1	13	0	9	3	0
Nariño	-	15	24	3	2	5	12
Pamplona	5	12	9	13	3	0	0
Pedag. y Tech.	19	12	16	15	11	15	15
Quindío	15	15	15	18	20	20	25
Surcolombiana	-	14	7	8	5	11	12
Tecn. Chocó	15	17	12	0	13	18	20
Tecn. Magdalena	5	3	10	4	2	5	2
Tecn. Pereira	52	33	40	26	29	30	35
Del Valle	3	23	29	24	24	14	19
TOTALS	124	150	184	116	137	136	145
Index		100.0	122.7	77.3	91.3	90.7	96.7

The tables indicate that both total enrollment and number of graduates have been decreasing. One university (Quindío) is not accepting any students for the Licenciado degree in mathematics-physics. In general the number of graduates is small compared to the enrollment, indicating a high dropout rate. The tables also show that enrollment is high in universities located in small cities such as Chocó, Pamplona, and Surcolombiana. The situation is a result of the very limited options or careers offered by these institutions.

Another reason given for the low number of graduates is that the market for secondary school teachers is saturated and many students decide to go into other fields before they complete their degree. In reality the need for more secondary school teachers has been established, but the government has been unable to increase the number of positions. Besides, the salaries for secondary school teachers are very low compared to professionals in other areas or fields.

Finally, the high rate of students dropping from the Licenciado degree has been attributed to a lack of vocation for teaching in many students and also to the limited possibilities for students to be accepted in other careers. (Many universities have limited the enrollment in most of the careers being offered.) Thus students enrolled in the "Licenciado" degree later on change to other careers in the University.

The duration of the programs for a "Licenciado" degree varies between eight to ten semesters, depending on whether students are full-time or part-time. Table 12 shows some data related to the number of courses in physics (semesters) and the area. The letters MP indicate mathematics-physics, and M indicated mathematics. P is used for a degree with a major in physics.

Table 12. Licenciado in Education (Secondary School Teacher).

University	No. of Semesters	No. of Courses		
		Physics	Total	Major
Amazonía	10	10	45	MP
Nariño	8	13	44	P
Pedag. y Tech. de	8	10	48	MP
Colombia		15	48	P
Quindío	8	15	36	P
Surcolombiana	9	14	45	MP
Tecn. Chocó	9	12	46	MP
Tecn. Magdalena	9	11	45	MP
Pereira	9	13	42	MP
INCCA	8	8	44	MP
Valle	10	10	37	MP

The Undergraduate Degree in Physics

As previously mentioned, the undergraduate degree in physics, called the degree of "Fisico," is offered only in five institutions in Colombia: four state universities and one private institutions.

In information given in Tables 13 and 14 is related only to the state universities.

Table 13. Total Enrollment for the Degree of Physicist (Undergraduate Degree in Physics).

University	1980	1981	1982	1983	1984	1985	1986
Antioquia	104	92	83	98	103	126	130
Ind. Santander	-	-	-	-	-	-	-
Nacional	79	28	30	37	-	75	69
Valle	67	61	56	72	83	71	66
Totals	250	181	169	207	216	312	328

The total number of students who received an undergraduate degree in physics is 537. Universidad de Antioquia has graduated 51, Universidad Nacional 405, and the Universidad del Valle 81. It has been estimated that the total number of graduates from Colombian universities with a degree of physicist is about 550.

Table 14. Graduates with the Degree of Physicist between 1980-1986.

University	1980	1981	1982	1983	1984	1985	1986
Antioquia	1	6	3	5	5	1	5
Nacional	16	17	6	21	18	9	15
Valle	5	7	10	-	-	11	7
Totals	22	30	19	26	23	21	27

Table 15 shows the number of semesters and courses required in some universities for the degree of physicist.

Table 15. Courses Required for the Degree of Physicist.

		Number of Courses	
University	No. of Semesters	Physics	Total
Antioquia	10	10	48
Industrial de Santander	10	24	50
Valle	9	24	39

The number of courses and semesters required for the degree of physicist are higher than those required for undergraduate degrees in other industrialized countries. Colombians consider that it is necessary, because the possibilities for advanced degrees are limited, and in this way the basic preparation of the future professional in physics is better.

The professors in the Colombian universities dedicate most of their time to teaching. However in the best-developed institutions, professors are doing some research in certain fields of physics. Table 16 offers some information about teaching and research. Under the "other" colume, activities such as development of teaching materials, interaction with secondary schools, organization of science fairs, etc. are included.

Table 16. Time Dedicated to Teaching, Research, Other

University	Teaching (%)	Research (%)	Administration (%)	Other (%)
Amazonía	100	0	0	0
Javeriana	80	10	10	0
Nariño	80	10	10	0
Pamplona	70	10	20	0
Pedag. y Tecn. Col.	86	7	7	0
Quindío	68	16	16	0
Sucre	95	0	5	0
Surcolombiana	80	9	7	4
Tecn. Chocó	86	7	7	7
Tecn. Magdalena	100	0	0	0
Tecn. Pereira	85	5	10	0

Table 16 continued on next page.

Table 16. (Continued)

University	Teaching (%)	Research (%)	Administration (%)	Other (%)
Antioquia	70	20	10	0
Ind. Santander	60	31	9	0
Nacional	63	25	12	0
Valle	59	17	15	9

Graduate Programs in Physics

The graduate programs at a Master's Degree level (Magister) were initiated in Colombia at the beginning of the 70s in the Universidad Nacional de Colombia (Bogotá), Universidad del Valle (Cali), and Universidad Industrial de Santander. During the same decade a Master's program was initiated at the Universidad Pedagogica Nacional. This program at present is clearly established as a Master's program in teaching physics; however, there is no data available about this program. The Universidad de Antioquia (Medellin) established a Master's program in physics in 1982.

Tables 17 and 18 include some data about enrollment and graduates.

Table 17. Enrollment in the Master's Program (Magister in Physics), 1980-1986.

University	1980	1981	1982	1983	1984	1985	1986
Antioquia	--	--	20	10	30	25	13
Ind. Santander	26	32	34	32	30	26	14
Nacional	16	16	16	16	16	16	16
Valle	5	11	14	9	12	13	19
TOTALS	47	59	84	67	88	80	62

Table 18. Graduates from the Master's Program.

University	1980	1981	1982	1983	1984	1985	1986
Antioquia	--	--	--	--	--	5	17
Ind. Santander	6	1	4	6	--	9	4
Nacional	21	13	1	2	3	2	1
Valle	--	--	3	3	3	1	8
TOTALS	27	14	8	11	6	17	30

Students in the Master's program must complete a thesis as a requirement for graduation. Another interesting aspect of the graduate programs in Colombia is the establishment of a degree of "Especialista" (specialist). This degree does not require a thesis but could include some work on design and/or construction of equipment or preparation of a monograph. The Universidad Nacional has established two of these programs. The first one is a joint effort with the Universidad Pedagógica y Technológica de Colombia (Tunja) on

Specialization in Physical Science. The other program on Specialization in Health Physics is being developed in collaboration with the Institute of Nuclear Affairs (Instituto de Asuntos Nucleares).

The Universidad de Antioquia has extended its Master's program to the city of Pereira by agreement with the Universidad Technológica de Pereira. Some professors from the latter institution have been able to do graduate work through this program.

The "Instituto Colombiano para el Fomento de la Educación" (Colombian Institute for the Development of Education) is trying to promote a new program for the development of the sciences and engineering using funds from the Bank for International Development. Investment in this program will be about 2.2 million (U.S. dollars) in equipment for graduate work, international scholarships, contracts with international experts, and libraries.

Efforts to Improve Physics Education at All Levels

Several programs have been established in the Colombian universities since the 1970s to improve physics education at all levels.

The Universidad Nacional and Universidad de Antioquia now have graduate programs offering the degree of "Especialista" (specialist) in physics teaching. Both institutions have established new classrooms for demonstrations that are offered to secondary school students.

The Universities of Nariño and Surcolombiana have done some diagnostic work in teaching physics at the secondary school level, and the Universidad Surcolombiana has designed some instructional packages for teaching physics. It has also organized science fairs and science clubs both at the secondary and university levels.

In the Universidad Technológica de Pereira, work is being done on the use of microcomputers in physics teaching. The Universidad Pedagógica Nacional (Bogotá) has several projects in research and development of teaching materials, but there are not specific data available about these projects.

In 1978, the Universidad del Valle established the "Multitaller de Materiales Didácticos" (Unit for Teaching Materials) as an academic unit of the Faculty of Sciences. Several professors from the Faculty of Science and School of Education work in this unit. The major activity in this unit has been in physics education, on the design and construction of low-cost equipment. The equipment is built and sold to state and private secondary schools. Research in physics education is being carried in this unit of teaching materials and the results have been used in the preparation of physics teachers for secondary schools (Licenciados en Física).

A very intense teaching training program was initiated in the "Multitaller," and many of these programs have been offered for university professors and secondary school teachers. Some of the materials developed and used in connection with the "multitaller" of the Faculty of Sciences at the Universidad del Valle are:

1) Introduction to Graphs and Measurements
   Student's Guide by J. Garavito (33 pages); Teacher's Guide by R. Tobon (108 pages); and Mathematics Supplement by C. Soto (94 pages).

2) Introduction to Mechanics
   Student's Guide by J. Garavito (56 pages); Mathematical Supplement by C. Soto (64 pages).

3) Fluids
   Student's and Teacher Guide, by H. Guerrero and A. Perea (127 pages).

4) Heat
   Student's Guide by A. Perea, H. Guerrero, and E. Gutierrez.

5) Waves
   Student's Guide (42 pages) and Teacher's Guide (161 pages) by R. Tobon and E. Gutierrez.

6) Optics
   Student's Guide (81 pages) and Teacher's Guide (170 pages) by C. J. Diaz, H. Rivera, and R. Bernal.

7) Electricity and Magnetism
   Student's Guide (60 pages) and Teacher's Guide (144 pages) by R. Tobon and J. Marin.

There is a project on the Use of Microcomputers in Physics Education which has developed three interesting modules authored by C. Uribe and C.J. Diaz.

Several integrated laboratories for the sciences were developed in collaboration with the Secretary of Education of the region Valle Del Cauca and established in several cities of this region. Each of these laboratories offer their services to 10-15 secondary schools, and the university professors serve as consultants for the schools.

During the past few years a textbook Fisica: Principios y Aplicaciones has been developed to supplement the modules already mentioned.

Other efforts are being made in other institutions but there is no specific data about them.

The Professional Physicist

In spite of the tremendous improvements in physics education that have taken place in Colombia during the past 25-30 years, still the main activity of the professional physicist is academic--mainly teaching.

The majority of graduates from graduate programs in the country and abroad are university professors. The participation of physicists in industry is practically nonexistent, and the engineers are not used properly.

On the other hand, the state universities have serious budgetary problems and, the situation is not very promising.

Table 19 indicates the main activities of the physicists in Colombia.

Table 19. Main Activities of Graduates (Degree of Physicist).

Activity	No. of Graduates	%
University Professor	218	78.7
Research Institute	22	7.9
Secondary Education	4	1.4
Industry	2	0.7
Independent Professional	5	1.8
Specialization Programs	22	7.9
Working abroad	4	1.4
TOTALS	277	

COSTA RICA

General Information about the Country

Costa Rica, one of the most stable countries in the Americas, has a surface area of approximately 50,700 km^2 (19,575 square miles). The population is estimated at 2.41 million and the capital is San José.

The country is bounded on the north by Nicaragua, on the east by the Caribbean Sea, on the southeast by Panama and on the south and west by the Pacific Ocean. In the lowlands the climate is hot and humid with an average temperature of 27°C (81°F), but it is cooler on the Central Plateau where the average temperature is 22°C (72°F).

Costa Rica has a long democratic tradition. The elected president serves a four-year term and may not be immediately re-elected. Education has been a priority for all the governments. At present, approximately 30% of the national budget is being used for educational purposes.

The ethnic composition of the population in 1987 was: European descendants (mainly Spanish) 86.8%, mestizo 7%, Black-mulatto 2%, Chinese 1.9%, Amerindian 0.5%, and other 1.8%.

Literacy is among the highest in the Americas. The data available indicates that 94% of the adult population is literate. The official language is Spanish.

The economy of Costa Rica is based mainly on the export of coffee, bananas, cocoa, meat, and sugar. Bauxite has been discovered in the region of Boruca, and the government is trying to develop this new resource. The manufacturing sector includes food processing, textiles, chemicals, and plastics. Investment has been concentrated in the energy sector. Hydroelectric stations have been built in an effort to improve electricity demands. Petroleum production began on a small scale in 1984.

The Educational System in Costa Rica

The traditional concerns for education in Costa Rica have been clearly stated in the constitution. For instance, general basic education (educación basica general) is mandatory and free. Secondary education is also free but not mandatory. The constitution of 1949 also recognizes that professionals for teaching careers must be prepared in the institutions of higher education as one of the obligations of the government.

The administration of public education is under the Ministry of Education and since 1984, nineteen regional areas (Direcciones Generales de Educación) were established. Each of these regional areas is comprised of a certain geographical area. The "Direcciones Generales" are in charge of coordination, curriculum, control, and implementation of educational policies laid out by the Minister of Education and the National Council for Education (Consejo Superior de Educación) in each of the geographical zones.

The educational system of Costa Rica consists of four levels:

A) Pre-Primary Level. (Educación Inicial o Pre-Escolar)

A minimum of one-year duration.

B) General Basic Education Level.

This level of education lasts nine years, and is divided in three cycles--two cycles of primary education and one cycle of secondary education. The educational policy of this country--offering free and mandatory education at this level--has been very successful. At present 96% of the population between 6 and 14 years old are attending the general basic education cycle.

C) Diversified Education Level. (Educación Diversificada)

This level lasts about two to three years. It is not mandatory but is also free. During this educational level the student can select among three options or cycles:

i) Academic Option (Opción Académica)

During this cycle, general education in the sciences and the humanities is offered. It lasts two years.

ii) Technical Option (Opción Técnica)

This cycle or option lasts three years and is comprised of technical studies in agriculture, industry, and/or business.

iii) Artistic Option (Opción Artística)

The emphasis in this cycle is on education in the arts, music, dance, and theater. It lasts two years.

Completion of any of these options gives access to higher education.

D) Higher Education (Educación Superior)

The higher education level offers two options:

i) University level.
ii) Para-professional level.

The duration varies according to the career or technical preparation selected by the student.

University Level

The university level is offered by four state institutions and one private university. The state universities are autonomous but subsidized by the government.

The oldest university in Costa Rica is the Universidad de Costa Rica (University of Costa Rica), a state institution. It was founded in 1814 as "Casa de Enseñanza de Santo Tomas" and became "Universidad de Santo Tomas" in 1844. It was abolished in 1888 and re-established as Universidad de Costa Rica in 1940.

The main campus is the Ciudad Universitaria Rodrigo Facio. This University is comprised of several units known as "Facultades" (faculties), including engineering, sciences, education, etc. The faculties are subdivided into schools (departments). In addition, the University of Costa Rica has about 18 research centers and institutes.

Other important universities in the country are:

i) Universidad Autónoma de Centro America (Autonomous University of Central America) in San José. It is an independent institution authorized by the government.

ii) Universidad Estatal a Distancia (Open University) founded in 1977 as an autonomous institution supported by the State. This university provides access to higher education to students who are unable to attend regular university, particularly those living in rural areas.

iii) Universidad Nacional (National University) located in Heredia and founded in 1973 as a state or public institution.

iv) Instituto Tecnológico de Costa Rica (Technological Institute of Costa Rica) located in Cartago, with a Regional Center at San Carlos and an Academic Center at San José. It was founded in 1971 as a state institution financed by the government.

The universities in Costa Rica normally offer the undergraduate degree of "Bachiller" in several fields (3-4 years) and the degree of Licenciado and Magister in 2 or more years. The Universidad a Distancia (Open University) offers a diploma and the degree of "Bachiller" in certain areas.

The requirement for admission in the universities is the secondary school certificate or equivalent and an entrance examination.

The universities in Costa Rica also offer professional degrees in engineering, law, medicine, pharmacy, etc. Some of these universities have graduate programs, in particular the Universidad de Costa Rica.

The total enrollment at the university level is about 50,000 students.

Para-Professional Level

There are several technical or para-professional institutions offering technical preparation in business administration, accounting, agriculture, etc. The degree normally granted by these institutions is known as "Diplomado" (Diploma), and it takes the student two or three years to complete.

The following institutions are included in this category:

i) Instituto de Tecnologia Administrativa (Institute of Administrative Technology), located in San José, founded in 1980 as a private institution.

ii) Colegio Universitario de Alajuela (College of Alajuela) in Alajuela, founded in 1977 and officially recognized by the government in 1980.

iii) Instituto Superior de Administración de Empresas, located in San José and founded in 1972 as a private institution recognized by the government.

There are other para-professional schools located in Alajuela and Punta Arenas.

Before closing this section on higher education, it is worth mentioning the "Centro Agronómico Tropical de Investigación y Enseñanza," known as CATIE (Tropical Agricultural Center for Research and Training) and located in Turrialba. This institution was founded in 1942 as the "Instituto Interamericano de Ciencias Agricolas" (Interamerican Institute of Agricultural Science). It became autonomous in 1973 under its present title. It is supported and financed by governments of the Organization of American States, which are represented in the governing board (Board of Directors). Basically a graduate center, its program is offered in cooperation with the University of Costa Rica which awards the degree. The graduate programs are geared toward agriculture, forestry, and animal husbandry.

Table 1 provides some data related to the distribution of the student population at all levels.

Table 1. Institutions and Distribution of Students and Professors in All Educational Levels.

	Type and number of institutions		Enrollment		Number of Professors	
Level	Public	Private	Public	Private	Public	Private
Pre-primary (Pre-Escolar)	430	52	19,000	3,800	584	90
General basic education (primary, first level of secondary education & special ed.)	3100	43	346,000	9,000	11,700	430
Diversified education	216	26	164,000	10,300	7,750	320
University level	4	1	50,000	not available	4,340	not available
Technical (Para-professional)	3	5	not available	not available	not available	not available

Some statistics obtained for the dropout rate indicate that for the primary school level the rate is about 4% while it reaches 12% for the secondary school level. The data is applicable for schools operating during daytime. The schools operating during the evening hours have a higher dropout rate but the exact figures were not available.

Physics in Secondary Schools

During the third cycle of the general education level (first three years of secondary school), topics in physics are offered as part of the general science courses. The general science courses include topics in biology, chemistry, and physics. Students attend classes 42 hours per week and 4 or 5 hours are dedicated to general science. Teachers at this level normally complain about being unable to complete the topics in physics.

Physics, as a discipline, is offered during the first years of the diversified education level (grade 10). The course is mandatory and taught during three hours every week. During the second year of the diversified level, students should be able to enroll in a second optional course in physics (4 hours per week), but according to the data available very few schools at this level offer this option. It should be mentioned that students enrolled in the diversified cycle of agriculture do not take any physics courses.

The most common textbooks and supplementary texts used in physics are: Física, Fundamentos y Fronteras by Stolberg-Hill and Lecciones Elementales de Física by Juan de Oyarzábal.

The data obtained from a survey conducted among 50% of all the secondary schools (liceos) offering physics indicates that 40% of the teachers have a degree to teach in secondary school (not necessarily in physics); 10% are primary school teachers; 24% have a degree in science education (Bachilleres and Licenciados); 18% have degrees in chemistry and biology (Bachilleres), business administration and engineering; 7% do not have any degree and only 1% have a degree in physics (Bachiller).

A better sampling in the central region of Costa Rica (regions of dense population) showed that 65% of the physics teachers have a degree in teaching science; 14% have a degree (Bachiller o Licenciado) in physics, chemistry, or biology; 10% have a degree in mathematics and the rest of the teachers do not possess any degree.

It is evident that teacher preparation and lack of laboratory equipment in the secondary schools in Costa Rica are serious problems in physics teaching.

Preparation of Secondary School Teachers in Physics

The University of Costa Rica (Universidad de Costa Rica) is in charge of the preparation of physics teachers for secondary education. It was selected by an agreement among all the institutions of higher education in the country.

The University has used several approaches in the preparation of secondary school teachers. At present (1987) the degree being offered is "Bachiller en Enseñanza de las Ciencias" (Bachelor in Science Teaching) with majors in physics, chemistry, or biology. The graduate from this program can, if desired, continue studies toward a "Licenciado" degree in the specialties previously mentioned. These programs are joint efforts of the School of Education and the Faculty of Pure Sciences.

The curriculum leading to the degree "Bachiller en Enseñanza de las Ciencias" (Bachelor in Science Teaching) with a major in physics, is comprised of 8 cycles. Each cycle consists of 16 weeks of study and each week has an average of 27 hours of work per week. Physics is introduced during the third cycle (4 lectures per week). The prerequisite for this course is basic knowledge of differential and integral calculus. Students from other disciplines or careers requiring basic physics are also enrolled in this course.

During the fourth cycle another course in general physics is offered (4 lectures per week plus 3 hours laboratory). These courses are offered at the level of the textgook General Physics by Sears, Zemansky, and Young.

Two courses on topics in modern physics are offered during the fifth and sixth cycles (4 lectures plus 3 hours of laboratory per week). These courses include topics in solid state physics, nuclear physics, meteorology, astronomy, and some technological problems related to physics.

To complete the requirements for their degree with specialization in physics, students should take from four to five elective courses in physics.

Efforts to Improve the Preparation of Secondary School Teachers

The University of Costa Rica (Universidad de Costa Rica), the Technological Institute (Instituto Tecnológico), and the National University (Universidad Nacional) have offered some teacher-training programs for secondary school teachers. In addition, the Center for the Improvement of Science Teaching (Centro para el Mejoramiento de la Enseñanza de las Ciencias) in collaboration with the Universities in Costa Rica also offered several courses for secondary school teachers; however, some well-informed observers consider that these courses have not been very successful. The number of participants in these courses is low. Attendance has been estimated at less than 30% of the total number of teachers working in secondary schools.

Physics Education at the University Level

Physics courses have been taught in the universities in Costa Rica for many years. However, they were mainly basic courses for careers such as engineering requiring physics as a discipline.

In 1957, the Department of Physics and Mathematics was established in the Faculty of Sciences of the University of Costa Rica. The first steps were then taken in this Department to promote physics as a field and a career in the sciences. A plan was developed to prepare students in physics and mathematics which allowed them, upon graduation, to continue graduate work in institutions abroad. After a few years, when these graduates returned to the University, the School of Physics was founded.

The School of Physics now has several responsibilities. It is in charge of the curriculum and course offerings for the degree Bachiller en Física (Bachelor degree in Physics) and also offers the physics preparation and/or required courses in physics for students enrolled in the "Bachiller en Enseñanza de las Ciencias" (Bachelor degree in Science Teaching). In addition, students from all the other careers requiring physics must take their courses in the School of Physics. The number of students enrolled in the Bachelor degree in Physics has been maintained at about 15, graduating two or three per year.

Table 2 shows the enrollment of students in physics courses and the number of professors in three of the universities in Costa Rica.

Table 2. Physics Education in Three of the Universities in Costa Rica.

Institution	Total No. of Students	Students Enrolled in Physics Courses	No. of Physics Professors including their Degree Bach.	M.S.	Ph.D.	Licen.
Universidad de Costa Rica	30,000	2,000	8	11	12	15
Instituto Tecnologico de Costa Rica	1,500	600	7	3	--	--
Universidad Nacional Autonoma	15,000	Not Available	5	3	1	3

Graduate Studies and the Professional Physicist

Graduate programs in physics were established in the Universidad de Costa Rica in 1976 (Sistema de Estudios de Posgrado en Fisica). The main goals of the graduate programs were to prepare professors, researchers, and professional physicists capable of doing independent and creative work and able to make successful contributions to the society.

The "Sistema de Estudios de Posgrado" (graduate school) is in charge of the organization of curriculum and administration of the graduate programs. The programs are research oriented, and upon their completion the student will receive a Master's degree. The program requires the preparation and approval of a thesis.

The establishment of the graduate program has been very helpful for the improvement of physics education at the university level in Costa Rica. Three students have completed their Master's degree in the country and another nine students have received their degree abroad after doing some course work through the graduate program.

The graduate program in Physics in the Universidad de Costa Rica receives the cooperation of the School of Physics. Many professors worked in both components of the University. At present there are nine professors with PhDs and eight with MS degrees working part-time in the graduate program.

There is no data available about physicists working in industry or other professional activities except for teaching and research in the institutions of higher education.

ECUADOR

General Information about the Country

Ecuador is a country with an area of 283,561 km^2 or approximately 109,483 square miles. It is located in western South America, facing the Pacific Ocean (on the Pacific rim of South America). It is bounded on the north by Colombia, on the south and east by Peru, and on the west by the Pacific Ocean. The capital of Ecuador is Quito. Ecuador's name is derived from the country's geographical position.

The population, according to data obtained for 1987, is approximately 10 million, with the rural population being slightly lower than the urban population. Table 1 shows the actual and projected population growth to the year 2000.

Table 1. Population in Millions.

Year	1970	1980	1986	1990	2000
Urban Population	2.4	3.8	4.9	5.9	
Rural Population	3.7	4.3	4.5	4.9	
Totals	6.1	8.1	9.4	10.8	13.9 (projected)

The distribution of the population according to their age is indicated in Table.

Table 2. Distribution of the Population by Age.

Age	1970	1980	1985	1990	2000
0 - 14	45.4	43.2	41.8	40.5	38.4
15 - 19	10.6	10.8	11.1	10.7	10.3
20 - 64	40.3	42.6	43.4	45.0	47.6
65+	3.7	3.4	3.7	3.8	4.0

The population growth is estimated at about 3% per year, and the life expectancy has been steadily increasing since 1970, as can be seen in Table 3.

Table 3. Life Expectancy.

Year	1970	1980	1985	1990	2000
Life Expectancy	57.5	61.4	64.3	66.2	68.3

Ecuador's ethnic composition is formed by native Indians, Blacks (chiefly in the costal region), whites, and mulatoes. Spanish is the official language of this country, but large segments of the population speak Quechua or other indigenous languages.

According to the data available it is found that Ecuador has been investing 17.5% per year of the national budget in education at all levels during the period 1976-1984.

The leading export products are oil, fish, cocoa, bananas, and coffee. Since 1975 oil exports became the main source of income for this country. Other minor exports include forest products, rice, and copper.

The Educational System in Ecuador

The education of a student in Ecuador starts at the level called "educación de párvulos" (pre-primary or kindergarten). It is not mandatory, and children attend it when they are four or five years old. However, the educational system in Ecuador is comprised of three levels: primary, secondary, and tertiary or higher education.

Table 4 shows the enrollment of students in the different levels of education.

Table 4. Students Registered at the Different Levels of Education.

Level	Year	Enrollment
Pre-Primary and Primary Level	1980	1,534,000
	1985	1,789,000
Secondary	1980	587,000
	1985	759,000
Higher Education	1980	247,000
	1985	---------

A) Primary school level. This level is mandatory, and children must attend it between the ages of six to twelve years old. It is extended from grades one through six.

B) Secondary level. Students start in the secondary level, called "educacion media," at the age of 12. The secondary level requires six years to be completed and is divided in two cycles: i) basic cycle (ciclo básico) and ii) diversified cycle (ciclo diversificado).

The basic cycle comprised the first three years of secondary school and the curricula and programs are similar (common) for all the schools.

During the diversified cycle (last three years of secondary education), the emphasis is placed on specialization or orientation of the student toward i) college preparation or ii) vocational or technical preparation that will allow the student to enter the work force after finishing the secondary level. After completing the six years of secondary level, the student receives the degree of "Bachiller" (secondary school diploma), irrespective of the specialization selected.

The areas of specialization in the diversified cycle of the secondary level and the distribution of students in these areas are indicated in Table 5.

Table 5. The Diversified Cycle of the Secondary Level (1983).

Specialization	4th year	5th year	6th year	Total
Physics-Mathematics	24,237	17,043	13,500	55,270 (22.8%)
Chemistry-Bioloty	26,823	20,215	15,461	62,499 (25.8%)
Social Sciences	16,273	11,940	9,287	37,500 (15.5%)
Prep. for Teachers	1,205	1,249	645	3,099 (1.3%)
Subtotal	68,538	50,807	38,393	158,238 (65.4%)
Others: Technicians, Business, Arts, etc.	36,745	26,428	20,593	84,124 (34.6%)
Totals	105,281	77,235	59,846	242,362 (100%)

It should be mentioned that the majority of the physics courses are taught for the students in the physics-mathematics area of specialization. These courses are mandatory in this area. The students completing this specialization normally continue careers in the sciences and technology, especially in engineering. It should also be noticed that students enrolled in the areas of specialization of physics-mathematics and chemistry-biology are about half of the total population of students in the diversified cycle.

The efficiency of the educational systems at the secondary level are illustrated in Table 6. The data are given in thousands and the percentages are indicated in parenthesis.

Table 6. Efficiency of the Educational System (Secondary Level).

Academic Year	Enrollment	New Students	Students Repeating the Academic Year	Students Promoted to the Following Year	Not Promoted	Dropouts
1	176.4	156.8	19.6	120.5 (68.3%)	31.4(17.8)	24.4(13.9)
2	135.2	120.0	15.2	105.2 (77.9%)	19.1(14.1)	10.7(7.9)
3	113.8	101.3	12.5	89.6 (78.8%)	14.5(12.8)	9.6(8.4)
4	105.3	84.4	13.3	74.4 (70.7%)	16.6(15.7)	14.3(13.6)
5	77.2	69.7	7.5	63.8 (82.7%)	8.0(10.3)	5.4(7.0)
6	59.9	57.5	2.4	54.8 (91.5%)	2.3(3.8)	2.8(4.7)
Total	667.5 (100%)	589.5 (83.3%)	70.4 11.7%)	508.4 (72.2%)	91.8 (13.8%)	67.3 (10%)

It is estimated that the percentages indicated in Table 6 for 1983 have been maintained practically constant through 1987. If the situation presented in this table is analyzed, it can be noticed that only 22.4% of the students finished the secondary level without any failure or repetition of a certain grade. Also it can be seen that 44 out of every 100 students drop out of school before finishing their secondary education. There are no statistics about re-entry students, that is, students who drop out of school in a certain grade and then return back to school

Table 7 shows the relation between the number of secondary schools, professors assigned to those schools, and students enrolled. There are some extrapolations to the year 1996.

Table 7. Data on Students, Schools, and Professors in the Secondary Level.

	1966	1976	1983	1986	1996(estimated)
Schools (x 10^3)	0.55	1.04	1.93	2.12	14.9
Professors (x 10^3)	10.39	23.32	38.83	47.21	112.9
Students (x 10^3)	134.31	382.71	667.52	722.55	1927.5
Students per School	245	386	345	341	129
Students/Professor Ratio	13	16	17	15	17

According to the data provided for 1986, the total number of secondary schools was 2118. This number includes schools supported by the state, city governments, and private sector.

This broad explanation on the secondary level is based on two important facts:

1) It is very important to concentrate the analysis in this document at secondary level and, in particular, on the diversified cycle

or specialized cycle, because it is in that cycle that students receive their first courses in physics with relatively higher intensity according to the specialty which they have selected. For many of them, the physics courses that they study and topics that they learn during these three years will be their only opportunity during their careers, or in fact during their lives, where they will be exposed to the subject of physics.

2) While many careers at the university level include courses in physics, there are no statistics available at the national level that will allow us to give information on the conditions and results at the tertiary level. The autonomy that the centers of higher education have (in other words, they are not governed by national laws) make it possible for the educational efforts to continue with a diversity of possibilities for the students and make it impossible to give some figures. The situation will be illustrated later on.

C) Tertiary or Higher Education Level.

The higher education level in Ecuador is comprised of about 20 universities and technical universities distributed among the cities of Quito, Cuenca, Guayaquil, Loja, Ambato, Babahoyo, Esmeraldas, Machala, Manabil, and Riobamba.

Access to this system is limited to those students who have finished the secondary level. The number of years that students spend in the tertiary level is variable, normally from three to seven years. It depends mainly on the degree or level of education they want to attain. Thus, the length of time and requirements involved vary from those who attain a degree of technologist to those who pursue a professional and/or doctor degree. The physical presence of the student, enrollment, and attendance is required at this level. However, parallel to this system and at the tertiary level, there are some projects called "educacion a distancia" or open university, mainly dedicated to adult education and to rural communities with no access to the regular university system. It is important to mention at this point the Open University System which is supported by "the Universidad Técnica de Loja" (Technical University of Loja), which is granting degrees in several traditional careers.

Theoretically speaking, the only requirement needed to enter the higher education level is the diploma from the secondary level (Bachiller). However, in practice, the universities use different mechanisms to control the access to the tertiary level. The system varies according to the institution of higher education. In some the diploma of completion of the secondary level is sufficient. Others have as a prerequisite for the student a very rigorous examination, in addition to their diploma. The limtied resources available to the institutions of higher education impose on them the establishment of "quotas," or limiting the number of students that can be accepted at tertiary level. Only those with better preparation are accepted.

Physics Education at the Secondary Level

The programs or curriculum of the first three years of secondary school (the basic cycle) so not include any courses in physics. There are some courses called natural sciences or "ciencias naturales" where certain properties of matter are treated. The topics are treated superficially and are very far form the systematic and experimental approach used in physics.

Formal courses in physics are taught during the last three years of secondary school (diversified cycle). These courses are taught in certain specialties and with different type of distributions or different levels, as indicated in Table 8.

Table 8. Physics Education during the Diversified Cycle of Secondary Education.

	Hours per week of Physics Instruction		
Specialization	4th year	5th year	6th year
Physics-Mathematics	5 theory + 1 lab	5 theory + 1 lab	6 theory + 1 lab
Chemistry-Biology	2	2	2
Technician	2 or 3 + 1 lab	2 or 3 + 1 lab	2 or 3 + 1 lab

The level of these courses varies extensively depending on such variables as the academic category or academic level of the school, the social category of the schol, the quality of the professors available, certain social and political problems, the number of hours available for teaching during the week, and the geographical situation of the school. There are big differences between rural schools, inner city schools, schools situated in the suburbs, etc.

The topics included in these courses assume that their level will be guided by the quality of certain texts recommended by the state, such as Alonso-Acosta, Alonso-Rojo, Valero, CEF, Maiztequi-Sabato, Soler, Alvarenga-Maximo, etc., and supposedly to be used by students. Recommended books for the professor are Alonso-Finn, Haliday and Resnick, Zemansky and Young, Feynman, etc. However, the high cost of the textbooks, the diversity of pedagogical techniques used or approach being used and, of course, the ability for reading create a problem in using the textbook. This situation is very difficult to analyze. According to contacts maintained with professors and students throughout the country, it is possible to say that about half of the students who take courses in physics do not use the books, they just use their class notes. Of the other half, 25% of the students and professors use the textbook only to solve the problems and exercises.

The official rules of the national government, at the same time, establish that only persons with a degree such as "Licenciados" and Doctor in Education with areas of concentration in physics are allowed to teach this subject in secondary school. In practice, many professionals in other fields, mainly from engineering and other technical careers--the three-year-type technological careers--are also teaching physics. There is a large group of engineers and others who are teaching the subject. Table 9 shows an approximate distribution by sex and level of education of the secondary school teachers.

Table 9. Secondary School Teachers (Data 1983).

Degree	Male	Female	Total	%
Doctor in Education	415	401	816	(2.1)
"Licenciado" in Education	8,225	6,635	14,860	(38.27)
Other University Degrees (Engineering, Medicine, Law, etc.)	5,452	2,069	7,521	(19.37)
"Normalistas" (Degrees in Primary School Teaching)	123	77	200	(0.52)
Appointed by the Secretary of Education	437	316	753	(1.94)
"Bachiller" in Education (Bachelor Degree in Education)	1,422	1,015	2,427	(6.28)
"Bachiller" in the Humanities (Bachelor Degree in Modern Humanities)	4,247	2,082	6,438	(16.3)
"Bachiller" Tecnico/Artes/Comercio (Secondary School Diploma)	2,967	2,539	5,506	(14.18)
Less than "Bachiller", Other	259	159	409	(1.05)
Totals	23,537 (60.6%)	15,293 (39.4%)	38,830 (100%)	

It is very helpful to look at the distribution of the professors at this level by their professional title or (in other words) by their degrees and also by their sex. The information in Table 9 indicates that only about 40% of the personnel dedicated to teaching at the secondary level is formed by professors with a degree related to education or professionals in education that include Doctors in Education and "Licenciado" in education. The rest of the secondary school teachers are in possession of other degrees such as engineering, medicine, law, etc. Moreover, these figures clearly indicate that teaching at the secondary level is dominated by males. The reason, basically, is that many of the traditional careers that are not directly in the field of education such as medicine and engineering have been fields dominated by males, for cultural and historical reasons that are well known in the Spanish-speaking countries. It is expected that this tendency will change in the decade of the 1990s as a consequence of the cultural transformation that has been taking place in Ecuador since the 1970s.

A very recent survey done between professors of physics from different regions of the country used in the preparation of these documents indicates that in addition to the data previously given, there are other problems in physics teaching at secondary school level. For example:

A) At least 70% of the professors trained by schools of education and universities should be receiving intensive programs to strengthen and to update their knowledge of physics.

B) At least 40% of the schools do not have adequate laboratories for teaching physics. In many cases the laboratory equipment and materials are obsolete or the laboratories are poorly equipped.

C) In the schools that have adequate laboratory facilities, about 80% of the professors of physics lack the background and knowledge to use the laboratory as an integral part of the teaching process. In many cases the laboratory component of the physics courses is handled by assistants, who have very poor preparation in the subject. The laboratory component is then not linked to the theory taught in physics.

D) The programs are very intense--encyclopedic type of curriculum--and in order to comply with them, there is very little time to apply new techniques of teaching or new approaches in teaching physics.

E) The majority of the students lack the ability for comprehensive reading in using textbooks.

F) The mathematical preparation of the student is very mechanical. In other words, the students enter the physics courses with very elementary abilities in the use of logic and understanding of the material.

G) The salaries of secondary school teachers are very low and, consequently, they are forced to work part-time in two or three schools, jeopardizing the concept of the full-time teacher in one school. The teachers are not able to prepare their classes properly using modern strategies. They do not have the time to update their courses and/or their knowledge of the subject.

As a consequence of all these problems mentioned above, the students are perhaps able to repeat formulas and definitions, but they cannot apply their knowledge to any situation in their life. The system, in general, is not efficient.

Preparation of Physics Teachers for the Secondary Level of Education

To analyze this topic it is necessary to keep in mind that approximately 50% of the secondary school teachers do not have the appropriate degree to teach at this level. As previously mentioned, many of them are professionals in other fields. In many cases their preparation is in technical fields related to physics. Other teachers are university students who are preparing themselves for professional and scientific careers. In certain cases these professors have only finished a degree in secondary education. We must assume that the percentages for high school teachers with the appropriate degrees are very close to those established in the table for professors in all areas. However, in this section we will be referring only to those secondary school teachers who are prepared in the schools of education.

The structure of the higher education in Ecuador establishes that only the schools or faculties in educational sciences are allowed to prepare professors for the different areas in the secondary level. This means that the schools (or faculties) of education prepare students in those areas of teaching such as methodology, evaluation, etc., but at the same time these schools offer the major areas of concentration. For instance, in the case of teachers of physics, the school of education offers the courses in physics and mathematics required for the preparation in these areas.

In Ecuador there are 20 universities; of those, 13 have faculties or schools of education and in eight of these faculties, there are schools for preparation of teachers in physics and mathematics. It is interesting to note that any person with a degree in physics is also a professor of mathematics; the specialties go together.

These are the only characteristics in common among the different schools for the preparation of physics teachers. In all other aspects each institution is different, thus, it is not possible to describe what is the general situation or to take an overview of how these professors for secondary schools are prepared.

Table 10 shows a comparison between the least efficient and the most efficient school for the preparation of secondary school teachers in physics.

Table 10. Comparison between Two Typical Schools for the Preparation of Physics Teachers for the Secondary Level.

		Most Efficient School	Least Efficient School (Poor Program)
1.	Hours per week (Physics)	7 hours theory 2 hours laboratory	3 hours theory Laboratory occasional
2.	Duration of Studies	a) 4 years, 8 semesters 5 months each) for undergraduate degree. b) One more year for Doctor of Education.	a) 4 years, 4 periods of 9 months each for undergraduate degree. b) One more year for Doctor of Education.
3.	Textbooks, References	Halliday-Resnick Zemansky-Young Beiser, Brophy	Professors do not assign any textbooks or references.
4.	Programs, Topics	Mechanics, Fluids Waves-Acoustics Thermodynamics Electromagnetism Electronics Modern Physics	Mechanics, Fluids Heat and Temperature Electrostatics
5.	Number of Students Registering	30 per year	280 per year
6.	Number of Students Completing Course Work	10 per year	50 per year

Table 10 continued on next page.

Table 10. Comparison between Two Typical Schools for the Preparation of Physics Teachers for the Secondary Level. (Continued)

		Most Efficient School	Least Efficient School (Poor Program)
7.	Number of Students Graduating	5 per year	Unknown
8.	Degree Received	a) Licenciado (Thesis in Education) b) Doctor in Education	a) Professor of Secondary Education (No Thesis) b) Licenciado (Monographic work) c) Doctor of Education (Thesis in Education)
9.	Level of the Professors	Faculty members have M.S., B.S., and Licenciado degrees.	Faculty members have Licenciado degree in Education, Dr. of Education, Engineers.
10.	Option for Graduate, Post-Grad. Work.	Medical-Physics	None

It is assumed that in the eight schools for the preparation of physics teachers, about 680 students complete their preparation per year. However, only about 50% obtain their degree of "Licenciado" which is one step above the preparation for a regular secondary school teacher. Those receiving Doctor's degrees are very exceptional cases.

Other careers or degrees that include physics courses are shown in Table 11.

Table 11. Physics Courses Taught for Some Undergraduate Degrees.

Career	No. of Years	No. of Courses	Textbook Level	Professors' Degrees	Course Contents
Engineering (Polytecnic Schools)	2	4	Halliday-Resnick	Master in Science, Engineers	Classical, General Physics
Engineering Technology	1	2-3	Tipler Alonso-Rojo	M.Science, Engineers, Technolo.	General Physics
Engineering (Universities)	1	1-2	?	Engineers B.S.	Mechanics Fluids
Others	1	1	?	Engineers	Mechanics

Projects for the Improvement of Physics Education

There are some sporadic efforts by some secondary schools or isolated groups of professors to improve physics education. The most important projects are described as follows:

A) Escuela Politecnica Nacional (Quito). For almost six years, teachers of the so-called Department of Basic Sciences (Departmento de Ciencias Basicas) are maintaining periodic encounters or workshops with professors of physics at secondary level of the north-central area of Ecuador. They organize seminars on updating, knowledge of physics, and teaching techniques. Other types of meetings with an average of about 30 secondary school teachers have benefited about 240 teachers. More information on these workshops can be obtained from Prof. Abraham Ulloa in the Basic Science Department of Escuela Politécnica Nacional.

B) Escuela Superior Politecnica del Litoral (Guayaquil). For about ten years, especially during the past two years, the Institute of Physics of the Escuela Superior Politecnica del Litoral, which offers the courses in physics for schools of engineering and schools of technology, has been offering certain assistance to physics professors of the secondary level in the following areas:

i) Installation and organization of laboratories in schools that are receiving new equipment.

ii) Workshops on updating physics and on educational technology for professors at secondary school levels in the provinces situated in the south and on the Pacific coast of Ecuador. These types of workshops are offered by professors who travel to those cities.

iii) Workshops for updating professors on their basic knowledge of physics and using educational technology in secondary schools. These workshops and seminars are offered in the Escuela Superior Politecnica del Litoral. They are offered for teachers and schools of the city of Guayaquil.

There have been about 30 of those events or workshops with a total attendance of approximately 1000 teachers. More information on these programs can be obtained from Prof. Eduardo Molina, Director of the Institute of Physics of Escuela Superior Politécnica del Litoral.

C) The Sociedad Ecuatoriana de Fisica (Physical Society of Ecuador) not only unifies all the physicists in Ecuador but also accepts as members professors of physics at all levels. The SEF organized periodic seminars at the national level. An average of about 300 participants from the secondary level and some from the higher education level attend these seminars dedicated to new topics in physics, lectures about research in certain areas overlapping physics, seminars about educational technology, methodology of teaching, seminars about use of the laboratory, construction or preparation of equipment (low cost equipment), use of microcomputers in teaching physics, interaction with international figures in physics teaching, book fairs, etc. For the past six years SEF has organized five of those national meetings with an attendance of about 1500 professors. More information on these projects can be obtained from Prof. Abel Albán with the Institute of Physics at Escuela Superior Politécnica del Litoral.

Preparation of Physicists (Professional Physicists)

Until 1980 there was no school, faculty, or department dedicated to the preparation of professional physicists. Previously there were some physicists of national or foreign extraction who had obtained their preparation or degrees from universities in the United States and in Europe. By the end of 1980 the country had about five physicists with a PhD degree, 15 with a Master of Science degree, and three with a Bachelor of Science degree, all of them working at university level (teaching) in schools of engineering and schools of technology. Three of them are working on certain types of research in the "Comision Ecuatoriana de Energia Atomica" (Atomic Energy Commission of Ecuador) and a very limited number do consultant work for industry.

In 1980 in the city of Quito, the "Escuela Politecnica Nacional" opened the first department of physics in the Faculty of Sciences of this institution. The degree is obtained after 10 semesters of study. The first two semesters are common with the students in engineering. The degree granted is called "Físico." The academic level is comparable to a master of science degree from other foreign institutions. The graduates of these departments have the possibility of obtaining scholarships for specialization in other schools and centers abroad. It is not necessary for them to apply for or to receive a doctor degree from those institutions. It is intended that those who go abroad for specialization must be specialized in solid state physics and nuclear physics. Until now, the department of physics of the EPN has graduated three physicists, and 25 students are enrolled in the department pursuing this degree of "Físico." The department, at present, has three professors with a PhD degree, four with a Master of Science, two with the degree of "Fisico," and four engineers who also teach in the school of engineering. The department of physics of the EPN intends that those graduates from their institution could apply their knowledge in areas such as medical and health physics, energy, studies for the prevention of national disasters (environmental physics), consultants to industry and agriculture, and teaching physics at the higher education level.

Another physics department has been established in the Faculty of Sciences of the "Escuela Superior Politecnica del Chimborazo (ESPOCH)." This department started in 1984, has a curriculum divided into ten semesters, and the level is equivalent to a Master of Science degree. The first group of graduates is expected by 1989.

Ecuador is slowly moving toward improvement of physics education at all levels.

GUATEMALA

General Information about the Country

Guatemala is one of the Central American countries. It has a surface area of approximately 108,889 square kilometers or 42,042 square miles. The country is bounded on the north and west by Mexico, on the east by Belize and the Caribbean Sea, on the south by the Pacific Ocean, and on the southeast by Honduras and El Salvador.

The 1985 population was estimated at about 7.96 million, based on the projections of the 1981 census. The ethnic composition is approximately 50% Indian, nearly half mestizo (predominantly in the cities), and whites and Blacks. The capital of Guatemala is Guatemala City with a population of 1.8 million (1985). Since the 1976 earthquake there has been a large concentration of the population in the capital. In fact, Guatemala City has about 37% of all the urban population. The next city in size accounts for only 3% of the total urban population in the country.

Guatemala has some very unique problems because, while the official language is Spanish, there are about 23 more languages with origins based in the Mayan civilization. Also, there are around 163 dialects.

The population growth is very high and is estimated at 2.8% per year. See Table 1 for a breakdown of the population by age. The population is distributed among urban areas (37%) and rural areas (63%). It is comprised of two socio-cultural groups: i) a group that maintains certain customs regarding their living accommodations, ways of dressing, communicating in their native language, etc. called "indígena" and ii) the rest of the population (westernized) called "ladinos" or non-indigenous. It should be noticed that these terms do not take into account the ethnic characteristics of the groups, but the division is based on socio-cultural characteristics.

Table 1. Distribution of the Population by Age (1985). Source: Guatemala Estimaciones y Proyecciones de Poblacion 1950-2025, DGE-CELADE 1985.

Age	Population	%
0 - 6 years	1,944,905	24%
7 - 12	1,329,367	17%
13 - 18	1,067,672	13%
19 - 24	854,876	11%
24 and above	2,766,536	35%
Total	7,963,356	100%

Illiteracy is, in general, very high, especially among the "indigenous population." According to the 1981 census, illiteracy among the population 15 years or older was almost 44%. Table 2 gives a better idea regarding illiteracy among the two socio-cultural groups.

Table 2. Illiteracy among the Socio-Cultural Groups.

Area	Group "Indigena"	Group "Ladina"
Urban Area	49%	10%
Rural Area	73%	42%

According to the data obtained for 1985, 14.5% of the budget was assigned to the Ministry of Education and only 7.9% was budgeted for the Ministry of Health and Public Assistance.

Guatemala's income is mainly provided by exports of agricultural products, with coffee as the main source of revenue. Other exports include cotton, bananas, sugar, and meat products.

The Educational System in Guatemala

The educational system in Guatemala has been uniform throughout the country. That is, there were no differences in programs, curriculum, etc., according to the geographical regions. The constitution of 1985 states that Guatemala must be regionalized according to common socioeconomic characteristics of each region. By law, eight regions have been established and at present the educational programs are being modified according to the needs of each region. In addition, the constitution states that every citizen has the right, and also the duty, to receive education in the pre-primary, primary, and first level of secondary education according to his/her age as indicated by law.

In Guatemala there are four educational levels: pre-primary level, primary school level, secondary school level, and higher education level. Due to economic and cultural reasons, education at the first level (pre-primary school) has been better developed in the so-called urban areas. In the rural areas where the majority of the "indigenous" population resides, the main thrust of the educational level has been placed in teaching the Spanish language.

A) Primary School. Primary school is mandatory in this country for children between the ages of 7 and 14 years of age. It is extended for a period of six years from first through sixth grades. The student starts the primary school level at the age of six or seven years old. From a theoretical point of view he/she should finish the sixth grade at the age of 13. However, there are a lot of problems related to absenteeism and repetition of a certain grade in primary school by the children. These factors play an important role in the extension of or the length of the primary school level. In addition, the total enrollment of students in primary school is only about 50% of the total population between the ages of 7 to 14 years.

B) Secondary School. The secondary school level is divided into two cycles: the basic cycle and the diversified cycle. The basic cycle is comprised of three years of general education. It is common to all the students; in other words, there are no elective courses. The diversified cycle offers several options. These options give possibilities in both the sciences and the humanities, and in the so-called vocational and professional specializations. The duration of this cycle for the sciences and humanities option is two years. It lasts three years for the vocational and professional fields.

C) Higher Education Level. The higher education level is comprised of schools at the university level and also by certain faculties for undergraduate education in the universities. In Guatemala there are five universities: one national university supported by the state and four private institutions. The largest institution of higher education is the Universidad de San Carlos de Guatemala (University of San Carlos de Guatemala). It was founded in 1676 and became an autonomous institution in 1945. This public institution is mainly financed by the state with a student enrollment estimated at about 38,000. The other four private institutions are:

i) Universidad Francisco Marroquín (Francisco Marroquín University) founded in 1971.

ii) Universidad Mariano Gálvez (Mariano Gálvez University) founded in 1966.

iii) Universidad Rafael Landívar (Rafael Landívar University), founded in 1961 as a private Catholic institution recognized by the state. Status of independent university attained in 1966.

iv) Universidad del Valle de Guatemala, founded in 1961 as a private institution. Formally recognized by the state in 1966.

The undergraduate education lasts, in general, five years in all these institutions. In some particular cases the higher education system includes graduate work to the Master's level and also the Doctor degree level. The latter one is very small compared to the Master's programs. The duration of these graduate programs is variable. For example, a Master's degree could be obtained in one year, two, or even more depending basically on the time that the student dedicates to pursue this degree (full-time or part-time basis).

In Guatemala every student who has completed the secondary school level including both cycles has the opportunity to be enrolled in the university. Table 3 indicates the enrollment of the students at primary, secondary, and higher education levels during the years of 1984 and 1985.

Table 3. Enrollment of Students According to the Educational Level.

Educational Level	Number of Students 1984	1985
Pre-Primary Level	132,655	133,726
Primary Level (children)	979,888	1,010,474
Primary Level (adults)	24,267	25,454
Secondary Level (Basic Cycle)	128,008	134,292
Secondary Level (Diversified Cycle)	66,476	62,940
Totals	1,331,294	1,366,888

Physics Education in the Secondary School Level

During the past four decades the number of secondary schools has increased due to the population growth of the country. Before that period, there were secondary schools in the capital city and another three cities in the country. At present there is at least one center of secondary education for the basic cycle in each one of 22 important cities in the country and also in other cities with large populations. As a consequence of the population growth, demand for services at the secondary school level, and the establishment of new schols offering these services, there have been serious problems in obtaining or preparing adequate personnel to teach at this level. Initially primary school teachers and university students were used to teach at this level.

Around 1950, when the Faculty of the Humanities was established at the Universidad de San Carlos de Guatemala, a new program was started to prepare secondary school teachers. An opportunity was given to every person teaching at secondary school level without the appropriate credentials to return back to school. In this way they could obtain an adequate academic preparation. According to well-informed observers, this approach was successful only in the capital city (Guatemala City). The preparation of teachers for secondary schools was mainly oriented toward methodology of teaching but there was very little done regarding the different areas of specialization including physics.

In many disciplines it is possible to find personnel qualified to teach in that discipline; but this is not true, for instance, in the case of physics teaching. Many of the secondary school teachers lack the basic qualifications to teach physics.

The situation in Guatemala is not very different from that in other countries of Latin America. The majority of physics teachers in Guatemala at the secondary school level are primary school teachers from urban areas, also professionals with degrees in pharmacy or biology, students in engineering and, in a few cases, some students from the specialty of physics and mathematics. Most of them lack previous experience in methodology or evaluation. However, the opposite is also true. Many of the professors teaching at secondary school level have some background in methodology or pedagogy, but they do not have any training to teach physics at secondary school level.

We can summarize the situation in Guatemala by explaining that the majority of physics teachers at secondary school level come from the following sources: a) primary school teachers for urban areas without any previous training in physics, b) secondary school teachers graduated by the national university in the School for the Preparation of Secondary School Teachers (Escuela de Formacion de Profesores de Enséñanza Media). These teachers are prepared in a three-year program that has been modified on different occasions, and c) professors graduated from private universities such as Universidad del Valle de Guatemala, Universidad Francisco Marroquín, Universidad Rafael Landívar, and Universidad Mariano Galvez in which the curriculum varies from two and a half years to four years. This preparation is given on Saturdays. There are also students in engineering and some students from the licenciatura in physics who teach physics and are paid by the hour. There are other bureaucratic problems such as finding teachers of modern language teaching mathematics, professors of physics offering grammar, etc. In addition there are economic problems that force the teachers to work in two or three schools, creating serious social and educational problems.

As previously mentioned, during the past few years the universities in Guatemala have been offering the academic preparation for secondary school teachers, but there are no legal requirements in the country for physics teachers to be in possession of the appropriate university degree in physics. As a consequence, any teacher or any person with the secondary school diploma in science and humanities could be appointed to teach physics. At present only 2% of the physics teachers in secondary school possess a degree in physics.

To correct this problem the Minister of Education is requiring that after 1987, no teacher will be appointed to work in the secondary school level without the adequate university degree. This decision will have positive effects in the future but only for state-supported schools. This resolution will not affect those who are already teaching. They cannot be removed from their positions according to the civil service system.

As an additional comment, it should be added that there are practically no secondary school teachers working in extracurricular activities such as writing books, organization of science fairs, and preparation of teaching materials or audiovisual aids.

Two courses in physics are offered at the secondary school level: one in the third year of the basic cycle and another in the fouth year of the specialized cycle, for students receiving the diploma "Bachillerato en Ciencias y Humanidades," "Bachillerato Industrial," and "Magisterio de Educacion Primaria Urbana." These courses are offered for five periods per week with a duration of 35 to 45 minutes per period depending on the institution. It does not matter if they are state-supported secondary schools or private schools. The level of these courses is similar to those in the physics book by Alvarenga-Maximo. The contents of these courses are regulated by the state, and the manes of these courses are Fundamental Physics and Physics, First Course.

Preparation of Secondary School Teachers

In 1969 the School for the Preparation of Teachers for Secondary Schools--"Escuela de Formacion de Profesores de Enseñanza Media"--(EFPEM) was established. This school was under the direction of the Faculty of Humanities in the Universidad de San Carlos de Guatemala. It was a big step in the preparation of teachers for secondary schools in mathematics, physics, chemistry, and biology. The idea was to prepare the teachers in three years. Each participant received a scholarship and became a full-time student.

In the establishment of these schools for the preparation of secondary school teachers, new buildings were constructed using some international funds. These funds also were used to acquire new laboratory equipment, books, and other materials. In 1969 it was expected that these schools would be funded by UNESCO, the Universidad de San Carlos de Guatemala, and the Minister of Education; however, from the very beginning there were no contributions from the University and at the end of the agreement with UNESCO, schools were funded only by the Ministry of Education. The funds were reduced year after year until 1982 when the university took over the school. The scholarship plan ended and now the institution is in operation only during the afternoons. The students enrolled in the school for preparation of teachers are already working as secondary school teachers or as primary school teachers during the rest of the day.

One comment that should be made about these schools for the preparation of secondary school teachers is that they were too ambitious from the academic point of view. The graduates from these institutions acquired a very solid background. They were strongly prepared in physics, chemistry, biology, or mathematics. Thus, many of them decided to pursue careers in technical fields according to their background instead of improving their preparation as secondary school teachers. Many of them are now electrical engineers, "Licenciados" in pharmacy or biology, biochemists, or other types of professional careers, and they are working in their fields. Thus, the efforts to prepare them for a career in teaching were useless. On the other hand, the demand for teachers with the qualifications obtained from the EFPEM has been minimal because those already teaching without qualification cannot be removed from their jobs.

After 1969 many schools of education were established in the private universities of this country. These schools prepare secondary school teachers, but they attend classes only on Saturdays. In this way persons who are already teaching can continue working. The problem with the curriculum developed in these schools of education is that they are mainly focused toward methodology of teaching or pedagogy and the percentage of courses in the sciences is extremely low. In addition, the topics treated in those courses are superficial. In the case of physics many observers consider that the mathematical preparation required for this program is very low, and the university professors who offer these courses in the sciences, in particular in physics, do not have any degree in physics.

The Faculty of Science and Humanities in the Universidad del Valle de Guatemala, a private institution founded in 1966, has a pilot program for the preparation of secondary school teachers. The program is mainly oriented toward teachers already working in the secondary level. The program was started in 1986. The cost of attending the program is very low. In 1986 they prepared 22 secondary school teachers who are now able to teach the first course in physics in the basic cycle of secondary education. In 1987 two groups are being prepared: one of them with 15 participants to teach fundamental physics and another group of 15 to teach Physics I. During the program these teachers receive 106 hours a year of training--50% dedicated to the theory and 50% to the laboratory. These figures are, of course, approximate, and the level of the courses is similar to that included in the book by Halliday and Resnick. Table 4 summarizes the institutions offering teacher-training programs and graduates receiving this training.

Table 4. Institutions Offering Teacher-Training Programs and Graduates.

Institutions	Graduates
Escuela para la Formación de Profesores de Enseñanza Media (Universidad de San Carlos)	155 between 1966-1986
Facultad de Educación (Universidad del Valle de Guatemala) (Private)	46 between 1975-1986 (Includes all the teachers in Natural Science)
Departamento de Enseñanza Media; Facultad de Ciencias y Humanidades (Universidad Francisco Marroquín) (Private)	28 between 1982-1986
Facultad de Ciencias y Humanidades Universidad Rafael Landívar	69 between 1970-1986

Physics Teaching at the Higher Education Level

In addition to the teacher-training programs for secondary school teachers, the universities in Guatemala have undertaken the task of preparing highly qualified personnel in physics with a university degree. The degree "Licenciado" in physics was started in Guatemala in 1966 when the Universidad del Valle de Guatemala was founded. In the earliest stages of this program, it was necessary to bring personnel from the United States with a Doctor degree in Physics to help and support the national personnel. At the same time many students in Guatemala were sent abroad to be trained in physics or to receive graduate degrees. Since 1973 the teaching personnel of the physics department in the Universidad del Valle is of national origin. The first person to receive a degree in physics graduated in November 1973, and in 1976 the first person completed the requirements for the Doctor degree in Physics. Until 1981, the only physics department of significance in Guatemala was that of the private university previously mentioned.

In the other universities there have been other departments of physics distributed among the schools and faculty which require courses in physics but they were only offering service courses. It was in April 1981 that the Universidad de San Carlos de Guatemala decided to establish a "Licenciado" degree in applied physics in the Physics Department of the School of Engineering. Since then, however, there has not been any new degree in physics established at university level (see Table 5).

Table 5. Institutions Offering the Degree of Licenciado and Number of Graduates.

Institution	Students enrolled in 1987 (Licenciado in Physics)	Graduates in Physics between 1967-1987
Universidad del Valle de Guatemala	8	18
Universidad de San Carlos de Guatemala	22	1 (1985)

The number of courses in physics offered in the universities in Guatemala for students enrolled in careers in sciences or engineering varies between 54 and 62. However, it is not possible to make any comparison among them because the number of hours per week, level of courses, laboratory periods, and "credits" vary according to the institution.

In general, it can be said that the number of basic courses in physics offered in careers other than physics varies between two and five, and the level is comparable to that included in the textbooks of Halliday and Resnick and Sears-Zemansky.

Graduate Level in Physics

The only university offering a graduate degree in physics is the Universidad del Valle de Guatemala. One student received a Doctor degree in Physics in 1976, using the agreement of cooperation with the University of Texas at Austin. The advanced theoretical and experimental courses were taken by the candidate for the Doctor degree at the University of Texas. There has not been any other candidate to obtain the Doctor degree from the University del Valle de Guatemala.

At present there are only three persons with Doctor degrees or PhDs in physics working in Guatemala; however, there are four candidates working toward this degree abroad. No institution is offering the master's degree in physics in Guatemala.

Efforts to Improve Physics Education

A) As noted earlier, in the Universidad del Valle de Guatemala there is a teacher-training program for secondary school teachers in physics. The program is aimed at teachers who are already serving in the schools. It has been offered since 1986 and the activities are offered on Saturdays between the hours of 8:00 a.m. until 12:00 noon. The students enrolled in this program have to work 29 Saturdays between the months of March through October. During these four hours of work, the student has only a break of 20 minutes at mid-morning. The total number of hours amounts to 106.

The program is oriented toward improvement of basic knowledge on theoretical topics, laboratory activities, and problem solving. In addition, there are sessions on evaluation and also discussions about the evaluation system in secondary education. There is an active participation by the teachers of secondary school enrolled in this program and their interest in improving their skills is evident. More than 50% of these teachers come from cities or towns far from the capital where the university is located. The trip to the capital takes some of them almost four hours, which indicates the level of motivation of the participants.

The Universidad del Valle de Guatemala charges the student a symbolic quota, about one dollar at the current exchange, for the whole course. If the student teacher asks for an exemption from this quota, the course is given to him/her free.

The textbooks used are Física, (Dinamica de la Translacion) and Física (Dinamica Part 2) by Antillon and Cajas. The level of these books is similar to Halliday and Resnick. During this year the program expects to produce at least six videocassettes of 26 minutes each to help the student. Information on this program can be obtained directly from the director, Dr. Jorge R. Antillón-Mata, Programa de Capacitación de Profesores de Enseñanza Media en Física.

B) For several years the Universidad de San Carlos de Guatemala has been offering an annual event called The Mathematics Olympics. Since last year the department of physics of the school of engineering at this university worked together with other schools, and the Olympics competition in mathematics was transformed into the Scientific Olympics in which they had participants from secondary school students in mathematics, physics, chemistry, and biology. j This event was offered in the city of Guatemala, the capital city of Guatemala. This year the second Olympics is being extended to other cities. More information on this type of event could be obtained from Prof. Máximo Letona Estrada, Physics Department of the School of Engineering.

The Professional Physicist

Due to the fact that changes in the structure of the university system are relatively recent, there has been very little work done by physicists as professional scientists except for teaching physics at undergraduate level in the universities. The data in this report indicate that there are only three physicists with PhD degrees among the faculty in the universities in Guatemala and only 15 with the degree of "Licenciados"; but, according to some observers, this situation is an improvement if we compare it with the situation in 1980 when there were only two PhDs and seven professors without a degree in physics. Other activities in addition to teaching are practically nonexistant for graduates with degrees in physics. According to the available data, there is one person with a Licenciado degree in Physics who works independently in other tasks, in addition to teaching, since 1984. There is also a small number of physicists who have done some work with the government in 1986 and 1987.

Research in physics is, at best, in an early stage. There are very few opportunities to implement research in physics in any of the universities in the country. The only place where there is enough equipment for applied research is with the Minister of Energy and Mines, where they have some equipment in x-rays and some other electronic equipment. The Universidad del Valle de Guatemala has some equipment for nuclear magnetic resonance, detection of alpha, beta and gamma rays, and a spectrograph for atomic absorption and other equipment that is used in certain teaching activities.

The participation of the professional physicist in industry is practically nonexistent, and there is no indication that this situation will change in the near future. The only example that could be included according to the data provided is the efforts of one senior student (licenciado in physics) in the Universidad del Valle de Guatemala who has been working since the beginning of 1987 in the levels and intensity of sound in different industries. His efforts are aimed at convincing some industries of the need to establish certain maximum levels of sound (noise) for the protection of employees.

JAMAICA

General Information about the Country

Jamaica is the third largest island in the Caribbean after Cuba and Hispaniola (Haiti-Dominican Republic). It is situated 144 km (90 miles) south of Cuba and 160 km (100 miles) southwest of Haiti. The country has a surface area of 10,991 km^2 or approximately 4243.6 square miles.

Jamaica was governed by England until 1962 when it became independent, and many of its cultural and educational institutions automatically followed the British pattern. According to some observers, since then the country has been moving away from many of these influences and has adopted other forms from elsewhere that were thought suitable for Jamaica. In addition, the country has developed its own educational patterns in conjunction with other English-speaking countries in the West Indies, such as the Caribbean Examination Council (CXC), whose functions will be addressed later in this report.

The population of Jamaica according to the 1985 data is estimated at 2,366,000. The ethnic composition of the country is predominantly of African descent. It is considered that 76.3% of the population is Black, Afro-Europeans 15.1%, East Indians and Afro-East Indians 3.4%, whites 3.2%, and others 2%.

The capital of Jamaica is Kingston. Other important cities are Spanish Town and Montego Bay. English is the official language, but most Jamaicans speak Creole English.

One of Jamaica's major agricultural products is sugar cane, from which rum and molasses are made. The country also exports coffee, ginger, citrus fruits, cocoa, and tobacco, among others. Mining is a major source of income since the discovery of large deposits of bauxite. Jamaica has become one of the world's largest suppliers of bauxite. Other exports from the manufacturing sector are clothes, oil refining, and tobacco processing. The production of cement, textiles, and processed foods also has been important for the economy of the country since the late 1960s. However, tourism is still the second major component in the Jamaican economy.

The population is mainly rural (75%), but migration to the cities where industries are located is continuing. The population growth (1984) was estimated at 1.8% per year, with a life expectancy at birth of 65 years. The composition of the population by age is indicated in Table 1.

Table 1. Distribution of the Population by Age.

Age	%
0 - 15 years	38.4%
15 - 29 years	28.8%
30 - 44 years	13.9%
45 - 59 years	~9.4%
60 +	~6.9%

In some districts, according to the 1986 data, the literacy rate of Jamaica is approximately 76% (with compulsory education to age 14).

Educational System in Jamaica

The development of the educational system in this country is very interesting, arising from historical forces as well as recent social pressures. According to well-informed sources, it was the church which first encouraged the primary education system that afterward was taken over by the government.

The secondary school system in the early years (more than a century ago) grew out of the need to educate the planter's children. In particular, those who could not return to Europe were educated in Jamaica. The secondary schools were also run by the churches and by Trusts. Some observers consider that the influence of the church is still present in the composition of the school boards now established by the government.

In the 1950s and 60s more students entered primary school, and through a screening examination students received free places in the secondary schools. While there is an enormous variety of forms of education, almost all the children completing their primary education receive some post-primary preparation.

At present the educational system in Jamaica is comprised of the usual three levels: A) primary education, b) secondary education, and c) tertiary level. However, each of these levels has subdivisions which, in many cases, could be considered as a separate level.

A) Primary Education Level

This level includes nursery schools, sometimes referred to as pre-primary. It also includes primary schools, which are supported by the government, and preparatory schools which are private institutions. There is little difference in terms of the curriculum between preparatory and primary schools. Children attend the preparatory schools normally between the ages of four to eleven.

Education at the primary level could be obtained free even before independence even though private schools did exist. The cost to attend preparatory school in 1987 is estimated between 400 to 1700 Jamaican dollars per academic term.

B) Secondary School Level

The secondary school system in Jamaica is complicated. There is a great variety of secondary schools including about eight different types.

During the 50s and 60s the need to provide better opportunities for children to continue their secondary education was recognized. Using a screening examination in the primary schools, students were selected to receive free secondary education. Several types of secondary schools were established to account for the traditional interest in agriculture in the country, the incipient development of industry, and the inadequate preparation of the student from primary schools. According to well-informed sources, the results were not always satisfactory. The total number of secondary schools grew to the present number of 727, but about 59 of them can be considered in three main categories: technical and vocational schools, academic or high schools, and comprehensive schools.

The secondary level consists of two cycles, one of three years and another of four years. In general, it may be considered that the secondary level extends from grades 7 to 13. The age range for high schools is normally 11 to 19 years old, but at vocational schools, students enter at age 15.

There is a great shortage of schools at the secondary level, in particular, for the acedemic or high school subdivision.

Students who complete the primary level and who are candidates for the academic stream (high schools) must take a Common Entrance Examination to compete for a free place in the high school system. In recent years the number of students sitting in these exams has been in the order of 45,000, but only about 10,000 have been able to be placed in high schools simply because there are not enough schools. The other candidates go to other new secondary schools considered by observers as inferior in terms of the quality of education.

C) Tertiary Level

There are three main institutions in Jamaica at the tertiary level: a) the College of Arts, Science, and Technology known as CAST, which offers mainly degrees in technological areas; b) the College of Agriculture; and c) the University of the West Indies (Mona Campus). This university has three campuses in the Caribbean: one on the island of Trinidad with emphasis in agriculture and engineering; another campus on the island of Barbados (where the School of Law has been placed); and a third campus in Jamaica.

The College of Arts, Science, and Technology has 171 full-time and 113 part-time professors. The student population consists of 1986 full-time, 831 part-time, and 728 evening students. The University of the West Indies in Jamaica (Mona Campus) has 399 professors and 5,118 students.

Until 1986 the tuition at the tertiary level was free. The students now must pay a portion of their tuition at the University and Technical Colleges. Students are accepted in the University on the basis of examinations upon successful completion of the secondary level, as well as through scholarship examinations administered by the University. The normal age at which they take their exams is between 16 and 18 years old.

The University administers written examinations over the full range of science, arts, social science, agriculture, engineering, legal, and medical studies.

For the high school student, there are two school-leaving examinations, the ordinary or "O" level and the advanced or "A" level tests which are based on the English System. The "O" level test is equivalent to about grade 11 in the Canadian System of Education. Graduates from this level have been able to enter some U.S. universities. The "A" level (Grade 13) is more normal for the English-speaking West Indies and consequently for Jamaica.

There is a third type of examination for students finishing the secondary level called the CXC examination. It is offered by the Caribbean Examination Council which was created several years ago as a major examining body for the English-speaking West Indies, including Jamaica.

These examinations, mainly the "O" and "A" level tests, have been criticized for failing to allow for continuous or school-based assessment, for relying too much on memorization, and for failing to test special skills or aptitudes of students. The CXC examinations have addressed these points, but it is too early to say whether they are succeeding for physics.

Students interested in pursuing careers in the sciences may be accepted in the University with the "O" level test in science, except that it will take more time for them to receive a bachelor's degree (approximately 4 years).

The University offers a General Bachelor's Degree in two areas, and upon receiving this degree students are qualified to pursue graduate programs elsewhere. However, there is a higher level undergraduate degree (Special) in certain areas, similar to some of the British honor degrees in which the students concentrate on one subject only during their last year. This is particularly true in areas such as mathematics, chemistry, and physics.

The University also offers other degrees such as Master of Science (by examination) and the Master of Philosophy and PhD programs which require research. The University does not offer any post-doctoral program, certainly not in the sciences.

The College of Agriculture offers a three-year program in all aspects of agriculture. This college replaced the Jamaica School of Agriculture. The College of Arts, Science, and Technology offers diplomas and certificates in mechanical engineering, construction engineering, banking computing, technical teacher training, food science, etc.

Table 2 shows the number of students, teachers, and institutions at all levels in Jamaica as of 1980. It should be clarified that the table does not indicate the number of secondary schools. However, as previously mentioned, this number is approximately 72.

Table 2. Number of Institutions, Teachers, and Students at Different Levels (1980).

Level	Institutions	Teachers	Students
Basic School	1190	Not available	119,050
Primary School	894	8,676	359,488
Secondary School	Not available in 1980 (727 estimated at present)	7,525	248,001
Tertiary	11	Not available	9,451
University	1	397	4,548

It is interesting to mention that in 1983, 18.3% of the national budget was dedicated to education. In 1987 the percentage of the budget applied to education was only 10.3%.

Physics Education at the Secondary Level in Jamaica

As previously mentioned, there is a great variety of secondary schools in Jamaica but it is mainly in the academic or high schools, technical high schools, and comprehensive high schools where any serious physics education is offered.

General science is taught in the academic high schools during the first two grades (grades 7 and 8). Physics instruction begins at grade nine. The number of students enrolled per teacher in these schools is about 20, but the shortage of science teachers and, in particular, physics teachers is not reflected in these numbers. According to well-informed sources, the shortage of qualified physics teachers is very acute. Despite this situation, a fair number of students pass through the system and do some physics at the university level. In 1981, for instance, there were 116 "A" level passes in Physics and 32 students received a university degree in 1984 with a major in physics.

The lack of well-qualified physics teachers in Jamaica is very serious. Some observers consider that it is worse than in other countries of the western hemisphere. Several attempts have been made to solve the problem including the employment of teachers from overseas, with good incentives. However, the idea had to be abandoned due to serious financial constraints. Many schools do not have any physcis teacher and have to either drop the subject or arrange with the teacher of a nearby school to work part time for them. This occurs even at the ordinary or "O" level.

Some high schools have to use mathematics or biology majors, or even students who have not graduated, to teach physics. Thus, it is possible to find students graduated from "A" level (grade 13) teaching students in grades 10 and 11. In addition, many graduate students are used as teachers on a part-time basis.

As previously mentioned, a few years ago the Caribbean Examination Council (CXC) was established in the West Indies as the major examining body to test students completing their secondary education. An indication of the shortage of qualified physics teachers and its widespread nature was evident when the CXC had difficulty in finding six physics teachers with sufficient experience, competence, and interest to form a panel for writing the eleventh-grade physics syllabus.

According to some 1980 data corresponding to 32 major high schools, there were only 35 physics teachers compared to 80 biology teachers and 226 mathematics teachers. The total number of physics teachers in 1987 was estimated at about 50 but less than 20 are graduates in physics. A graduate with a "teaching diploma" receives a higher salary, but apparently this incentive has not attracted more physics teachers since only five of them are in possession of the graduate teaching diploma.

The problems of physics teaching at the secondary school level are complicated even further by the inadequacy of laboratory space, physical facilities, and lack of equipment. Many schools have to borrow equipment from the Physics Department at the University for the practical examinations offered at the ordinary "O" level and advanced "A" level. It should be mentioned that the limited facilities existing in many schools are used intensively.

The high schools and comprehensive schools are well provided with textbooks, but most of them are of British origin and some of them quite old. A rental system for textbooks has helped this situation.

Preparation of Secondary School Teachers

The preparation of teachers takes place at the University. The prospective science teacher, after obtaining a bachelor's degree, has the opportunity to gain a Diploma in Education. It requires a full year of academic work and teaching practice.

The University of West Indies is offering a new degree in science and education, but it is available only in the campus on the island of Barbados, not in Jamaica. However, there are strong indications that most of the students enrolled in this program are in the areas of chemistry and biology.

In recent years, with the expansion of the secondary education level, more teachers are being recruited from the teachers training colleges and relatively fewer enter the secondary teaching profession as graduates from the University. Some data given by concerned observers in Jamaica indicates that about 21% of the teachers in the three main types of secondary schools, namely academic, technical, and comprehensive, were not qualified.

Table 3 indicates the percentage of trained and untrained teachers, and their qualifications in the secondary school level.

Table 3. Qualifications of the Secondary School Teachers in Jamaica.

Secondary School-Type	Percentage of Trained Teachers w/University Degree	Percentage of Untrained Teachers w/University Degree	Percentage of Trained Teachers w/o University Degree	Percentage of Untrained Teachers w/o Univ. Degree
Academic	25.8%	17.5%	52.7%	4.0%
Comprehensive	10.7%	12.3%	68.7%	8.3%
Technical	10.0%	11.8%	73.5%	4.7%

The situation for science teachers and, in particular, physics teachers is worse than indicated in Table 3, but there was no specific data on this matter.

Physics Education at the Tertiary Level

The total enrollment of students in the tertiary level institutions previously mentioned (College of Arts, Science, and Technology, College of Agriculture, and the University of West Indies in Jamaica) is approximately 70,000 students, which is about 28% of the total secondary enrollment. Approximately 2,000 of these students have done some physics up to grade 11 ("O" level) and about 350 to grade 13 ("A" level) during their secondary education.

Assuming a four-year program, the first-year undergraduate physics course at the University of the West Indies in Jamaica has an enrollment of about 200 students. Many of them are not from Jamaica; they come from other territories in the English-speaking West Indies with the intention of pursuing a career in medicine. The second year physics course, which is post-advanced level physics (Post "A" level) has recently had an enrollment of about 170 students.

During the last two years of the undergraduate degree program, students have the option of pursuing a concentration in either "pure" or applied physics or in areas such as mathematics and chemistry. At these levels the student population in physics has been around 90 in the first (junior year in American universities) of the last two years.

During the final year, the number of students continuing into pure physics has been about 15, and 45 in the applied physics option.

There is also a possibility for the student to pursue the Special Degree in Physics but is is not normally offered to more than about 5 students.

Table 4 shows the figures for enrollment in the University of West Indies in Jamaica.

Table 4. Enrollment Figures at University of West Indies in Jamaica.

	1982-83		1985-86	
	Natural Sciences	Other	Natural Sciences	Other
University of West Indies (Jamaica)	1084	3472	1110	4330

Table 5 lists some of the physics textbooks used at different levels in the University of West Indies.

Table 5. Some Textbooks Used at the University of the West Indies.

Year	Textbook	Author
1st year	College Physics	Miller
2nd year	Physics	Halliday & Resnick
3rd year	Modern Physics	Sproul
	Electromagnetism	Grant & Phillips
	Physics of Vibrations & Waves	Pain
4th year	Operational Amplifiers	Clayton
	Optics	Hecht
	Solid State Physics	Hall
	Physical Metallurgy Principles	Reed Hill
(Special)	Statistical Physics	Mandl
	Quantum Physics	Eisberg
	Introduction to Optics	Fowles
	Classical Mechanics	Goldstein

It is interesting to mention that at the College of Arts, Science, and Technology there are nine teachers with a degree in physics. In the University of West Indies the number of professors (graduates in physics) is about 14, several of whom are in possession of PhD degrees.

Table 6 shows the number of graduates with a major in physics at the University of West Indies in Jamaica.

Table 6. Graduates in Physics between 1980-1986.

	1980	1981	1982	1983	1984	1985	1986
No. of Graduates Bachelor's Degree-Major in Physics	32	13	33	51	32	39	33

The number of graduate degrees and/or diplomas during the same period (1980-1986) was: Diploma in Applied Physics - 6; Master of Philosophy - 3; PhD - 2.

Efforts to Improve Physics Education at All Levels

Several efforts have been undertaken in Jamaica to improve physics education. In the past, the University of West Indies and other institutions at the tertiary level have offered refresher courses for physics teachers. These efforts have decreased recently. However, the Caribbean Examination Council (CXC) has been offering workshops and orientation courses for teachers who have to work with the new "O" level physics course (grade 11). CXC has also developed some new materials on energy and the history of physics which have been included in the new physics syllabus.

The physics department at the University in Jamaica, under the sponsorship of the Organization of American States (OAS), prepared a book for the physics teachers in the Caribbean (1975) which includes historical episodes, troublesome topics, and inexpensive experiments. This guide has been very useful to the resourceful secondary school teachers. In addition to this publication, the Physics Department at the University in Jamaica offered a course on physics teaching for several years. This course was not equivalent to a teaching diploma.

There is an annual Science Exhibition offered in Jamaica involving secondary and, sometimes, primary schools. The Physics Department at the University in Jamaica has offered, on some occasions during the past decade, Open Days for Schools. Teachers, students, and others interested in academics were able to participate as observers of demonstrations in physics, to view some films, and to listen to some talks on certain topics in physics.

Some general science texts have been written for secondary schools, but the emphasis has been placed in integrated science. A new textbook in physics has been co-authored by a West Indian teacher. It is aimed toward the new CXC cyllabus in physics.

During the period 1980-86 some papers have been published by professors from the University at Jamaica and the College of Arts, Science, and Technology. The number varies widely from year to year. In addition to these papers, there have been several scientific reports as well as papers presented in scientific conferences.

The Physics Department at the University has been involved in conferences and meetings such as the Caribbean Physics Meetings sponsored by the Organization of American States in 1976 in Jamaica and in 1984 in Barbados. They were also involved in the Inter-American Conference on Physics Education in Oaxtepec (Mexico) in 1987.

Workshops on Corrosion and Bauxite Waste have been held in the Physics Department and/or initiated by the department. A School Workshop on Materials Science, recently offered, attracted participants from the Caribbean, other countries in the Americas, and England. This workshop was sponsored by the ICTP in Trieste.

The Professional Physicist

The majority of the physics graduates still can be found in academia, although there are a few in managerial positions in the government and in industry.

Those graduates with a Bachelor's degree in Physics mainly work as high-level technicians and rarely can be found doing research.

Table 7 indicates how physics graduates between 1984-86 are employed. There are indications that some of those who entered the teaching profession have not stayed in it (1987).

Table 7. Activities of Physics Graduates, 1984-86.

Year	Number	Employed as School Teachers	Employed in Industry	Other
1984	35	7	9	19
1985	13	1	2	10
1986	25	4	10	11

Some of the major research activities in physics in Jamaica are conducted at the University and the College of Arts, Science, and Technology. The Physics Department at the University has maintained some contacts with industry, offering some general advice and receiving some consulting contracts. For instance, the Department has been involved in studies on the feasibility of using windmills for power generation, studying salinity levels that might affect coffee production, and designing energy-saving devices for hotels and other businesses.

At the College of Arts, Science, and Technology (CAST), the major research activity is in the area of solar energy. Studies on solarimetry, design of solar energy devices (crop driers), physical properties of bauxite waste, and use of bauxite waste in construction have been made. In addition, some theoretical work on thin films and porous materials, electronics, and history and philosophy of physics is being conducted.

MEXICO

General Information about the Country

The United Mexican States (Estados Unidos Mexicanos) has a surface area of 1,958,201 km^2 or approximately 756,066 square miles. It is bordered to the north by the United States of America and to the southeast by Guatemala and Belize. The Gulf of Mexico and the Caribbean Sea serve as natural borders to the east, and the Pacific Ocean and the Gulf of California border Mexico to the west.

The climate in Mexico varies with altitude. The tropical southern region including the Yucatán peninsula and the Isthmus of Tehuantepec (southeast), and the lowland coastal areas along the Gulf of Mexico, the Gulf of California, and the Pacific Ocean are hot. The highlands of the central plateau are temperate. The north and west areas of Mexico include arid desert areas. Most of Mexico is mountainous, and about 20% of the country is forested.

Mexico is divided into 31 states and the Federal District, which includes the capital, Mexico City. Mexico City is the largest city in the country and one of the largest cities in the world.

The population, according to the data available for 1986, was estimated at about 78 million. The country has one of the largest population growth rates in the world, estimated at 2.8% per year. About 50% of the population is below the age of 15 years, and approximately 70% is below the age of 25 years.

The ethnic composition of the population according to the data available for 1981 was mestizo 55.0%, Amerindian 29.0%, Caucasian 15.0%, Black 0.5%, and others 0.5%. Life expectancy at birth (1980-85) was 63.9 years for males and 68.2 years for females. Mexicans are very proud of their ancient cultures and heritage. Mexico is one of the countries in the Americas that has taken care of their archeological treasures.

The official language in Mexico is Spanish but about 8% of the population, according to the data for 1970, speaks indigenous languages. According to the data obtained for 1984, literacy in this country was estimated at 82.6% in 1980 and was higher for males (85.5%) than for females (79.5%). The official figures are lower, but many Mexicans consider that illiteracy is still very high, in particular in the rural areas.

During the past few years much has been done to lower the rate of illiteracy at the adult level. Efforts in the field of adult education have resulted in a decline of adult illiteracy. According to some official estimates, this illiteracy among the adult population declined from 29% to 17% in 1980.

Mexico's principal source of income is petroleum exports. The oil industry and its derived products were nationalized in 1938 and the industry is administered by a state-petroleum agency known as Petroleos Mexicanos (PEMEX). The discovery of vast petroleum reserves in the regions of Chiapas and Tabasco enabled output to increase significantly in the 70s. The expansion of the oil industry provided the main stimulus to Mexico's economic development. Mexico is considered fifth in the world in its reserves of petroleum and natural gas. However, in recent years the country has experienced serious economic problems, accumulating a large external debt that coincides with a decline in the international price of oil.

Agriculture remains very important in the Mexican economy. The principal food crops include corn (maize), wheat, rice, and beans. The major export crops are cotton, coffee, fruit, and vegetables. The fishing industry is improving, with frozen prawns becoming a significant export.

Mexico produces a large number of minerals. It is the world's leading supplier of silver, celestite, and fluoride. Also, it is a major producer of mercury, cadmium, manganese, and zinc. Mexico's forests provide a variety of woods, but many observers consider that they are underutilized.

This country has one of the most advanced manufacturing sectors among developing countries. The leading products include refined petroleum and petrochemicals, steel, iron, motor vehicles, processed food, fertilizers, forest products, textiles, etc. However, tourism remains the second largest source of income after the petroleum industry.

Hydroelectricity, with an installed capacity of 6,532 megawatts, accounted for about 34% of generation in 1984. In spite of the well-trained personnel for the nuclear industry, Mexico has not yet made use of the Laguna Verde nuclear plant which was to start operations in 1987 (capacity 1300 MW).

Due to the enormous external debt and inflation, an austerity plan has been established. This plan has had a tremendous impact on the educational process in this country.

The Educational System in Mexico

Education is one of the most difficult problems to solve in Mexico. The enormous efforts toward improvement in education (particularly during the past 10-15 years) are not enough to overcome the gap between ancient traditions and the needs imposed by modern applications of science. Important progress has been made during the past 20 years, but Mexican observers are concerned about the future due to the economic situation.

Education is provided free at all levels in the public schools (supported by the government) and officially, it is compulsory at the primary school level. Recently compulsory education has been extended to include three more years at the secondary level.

The educational system in Mexico is divided into four levels: A) primary school level, B) secondary school level, C) pre-university level and technical school level (equivalent to senior high school), often known as "preparatoria", and D) higher education or tertiary level.

A) Primary School Level

Children normally begin the compulsory primary school at the age of seven. In many cases they attend pre-primary school (kindergarten) at the age of four or five. The primary school level extends for six years, from grades one through six. The number of schools at this level was estimated in 1984-85 at about 76,200 with a student population of almost 15,219,245, and 437,408 primary school teachers (34.8 student/teacher ratio).

The efficiency at this level is such that from every 1000 children enrolled in the first grade, less than half continue on to the second grade in primary school. It is estimated that only about 190 students for every 1000 who begin primary education complete this first level. These figures given in 1976 by the "Consejo Nacional de Ciencia y Technologia" (National Council for Science and Technology), known as CONACYT, still reflect the present situation in Mexico.

Science teaching at this level is rare or at best, if any science is offered, the quality of teaching is very poor. Some innovative projects at this level, including textbooks, teacher training, and experimental work, have had very little impact according to some observers.

B) Secondary School Level

The secondary level begins at age 12. It lasts for three years (age 12 to 15). In 1979 it was proposed to increase the period of compulsory education to this level (total of 9 years of primary and secondary education). The dropout rate of students is again very high. It is considered that for every 190 students admitted to the secondary level (those who completed primary school for every 1000 enrolled), only 80 complete this level.

Some Mexicans consider that teachers at this level are not well trained (particularly in physics), have low social prestige, and have very low salaries.

Table 1 shows some statistics related to the secondary school level, including public and private schools. Regular instruction at this level is about 30 hours per week during the three-year program.

Table 1. Statistics on the Secondary School Level (Source: Organization of American States, 1985).

Year	No. of students enrolled	No. of schools	No. of teachers
1981-82	2,231,362	9,958	170,433
1982-83	2,203,130	10,864	128,549
1983-84	3,277,579		130,473
1984-85 estimated	2,658,717	11,751	132,257

C) Pre-University and Technical School Levels

Students are normally enrolled in this level at the age of 15. It lasts for three years (age 15-18) except for those who choose to attend some technically oriented schools at this level where the program might extend for four years. Students receive the certificate known as "Bachillerato" after completion of the pre-university level.

It is worth mentioning that for every 1000 students enrolled in the first grade of primary school, only 80 reach the "preparatoria" (senior high school), and 58 complete the cycle before they are enrolled in the tertiary level. The quality and type of programs offered at this level vary. According to well-informed Mexican observers, there are some programs of very high quality and at a level comparable to excellent schools in the Western Hemisphere and Europe. However, there are other programs where the teachers lack basic preparation in the subject matter they teach and/or others who do not have any special pedagogical training.

Table 2 contains figures related to the number of students, teachers, and schools at this level. These figures include both the public and private sector.

Table 2. Statistics on Pre-University Education (Preparatoria) (Source: Organization of American States, 1985).

Year	No. of Students enrolled	No. of schools	No. of teachers
1981-82	1,140,610	2,058	16,024
1982-83	1,380,387	2,498	69,471
1983-84	1,475,340		74,801
1984-85 estimated	1,464,924	2,948	80,271

The schools comprising the pre-university level could be considered divided into different groups according to the entity responsible for the supervision of the academic programs, orientation of the curriculum (vocational, technical or academic), and/or administration of the schools. Most of these schools provide basic preparation for the universities in Mexico. The number of hours of instruction varies according to the student's interests and the institution. The following information cannot be considered official but is representative of some schools at this level.

a) Preparatorias

The schools known as "preparatorias" are funded by the government, but their academic programs are supervised, advised by, and in many cases controlled by some of the national universities in Mexico, in particular, in Mexico City and the metropolitan area.

For instance, the Universidad Nacional Autónoma de Mexico (National Autonomous University of Mexico), one of the largest and most prestigious institutions in the country, maintains the control of a large number of "preparatorias" in Mexico City. The program lasts three years, divided into six semesters. On the average, students receive 33 hours per week of regular instruction. Other universities in Mexico in different states have similar programs with "preparatorias" attached to them. The curricula is not uniform throughout the country.

b) Colegios de Ciencias y Humanidades (Schools of Science and Humanities), known as CCHs

This group of schools is a relatively new modality of the pre-university level. Their orientation is for the university-bound student. These schools are also funded by the government, but they are administered by and the academic programs controlled by the Universidad Nacional Autónoma de Mexico. The curriculum seems to be attractive. It takes three years to complete the program (6 semesters). The number of hours of regular instruction per week is about 20, except for the fourth semester which is 28. It is worth mentioning that the schedules and hours of instruction vary according to the student's interests.

c) Colegios de Educación en Ciencias y Tecnología (Schools of Education in Science and Technology)

These schools are another modality of the pre-university level and are supervised by the National Polytechnic Institute (Instituto Politécnico Nacional), a well-known technical institution of higher education in Mexico. Funds to support these schools are also provided by the government of Mexico.

The number of hours of instruction received by the student during the three-year program (six semesters) is 35. The curriculum is intended to be of very high academic level, but some observers consider it unrealistic according to the needs of the country and the students.

d) "Colegios de Bachilleres"

The curricula in these schools are also oriented toward the preparation of students for the universities. They are not supervised by any of the national university systems. Their academic supervision is provided by a National Autonomous Council and funded by the government of Mexico. The pre-university program in this modality takes three years (six semesters) to complete. The total number of hours of instruction varies on the average from 22, during the first and second semesters, to 28 in the third and fourth semesters. During the fifth and sixth semesters, students receive approximately 29 hours per week of regular instruction.

e) Escuelas Incorporadas (Private Schools supervised by the National University System)

Another group representative of the pre-university system is the private schools known as "escuelas incorporades" (Incorporated Schools). These private schools are supervised by several of the national universities. In the case of the "escuelas incorporadas" to the Universidad Nacional Autónoma de Mexico (UNAM), the curriculum is divided in years, not semesters, and the level of instruction is considered in some cases higher than that offered at public schools. Students receive, on the average, 30 hours per week of regular instruction. These private schools, in many cases, also offer the secondary school level (first three years previous to the pre-university level).

f) Escuelas Normales (Normal Schools or Schools of Pedagogy)

These schools comprise another modality for the pre-university level. They are centers primarily dedicated to the preparation of primary school teachers.

Students are admitted in these centers for the preparation of teachers at the age of 15 after completion of the secondary school level (secundaria). It takes about three years (six semesters) to complete this level. The students receive, on the average, about 35 hours per week of instruction.

Table 3 shows some statistics about "escuelas normales".

Table 3. Statistics on Schools for the Preparation of Primary School Teachers (Escuelas Normales) (Source: Organization of American States).

Year	No. of students enrolled	No. of schools	No. of teachers (faculty)
1975-76	111,502	---	8,396
1981-82	203,557	496	13,127
1982-83	192,062	545	13,318
1983-84 estimated	159,140	---	14,085
1984-85 estimated	102,347	594	15,777

There are other schools at this level (vocational and technical schools) which provide students with practical training (technicians). Their level and quality of education vary. Some of them are not recognized by the institutions of higher education, in particular, several of the private schools. As previously mentioned, students receive the diploma of "Bachillarato" after completion of the pre-university level, except for some vocational schools and the "escuelas normales." The latter will award the certificate of "Maestro de Educación Primaria" (Primary School Teacher). According to some statistical data (1984-85), the combined number of secondary schools and pre-university level schools (senior high schools) is about 17,620. The total number of students in these schools is 4,396,087 with 230,656 teachers (student/teacher ratio 19.1). Some of these figures, however, might be misleading because many teachers, particularly at the pre-university level, work in more than one institution on a part-time basis.

D) Higher Education or Tertiary Level

The higher education system in Mexico includes several types of institutions, both public and private. In many of them the quality and level of education is very high, offering both undergraduate and graduate degrees in several areas. In addition, many of them offer excellent professional programs. Others are considered of very low quality and can hardly be considered tertiary level institutions.

There were about 82 institutions known as universities in Mexico in 1985, but there are hundreds of other institutions known as "institutos technológicos" (technological institutes). Among them there are several prestigious institutions, such as the "Instituto Politécnico Nacional" (National Polytecnic Institute) a public institution, and the "Instituto Technológico de Monterrey" (Technological Institute of Monterrey) a private institution, where high quality graduate and undergraduate degrees are offered in several fields.

The International Handbook of Universities also includes a large group of institutions labeled as professional education institutions. They offer some professional degrees in areas such as law, economics, some branches of engineering, etc. Many of these institutions are recognized by the national universities and others are attached to the universities. Several of them are private. The level and quality vary among them.

Another group of institutions of higher education is comprised by the "escuelas normales superiores," considered teacher training schools. There are more than 20 of them in Mexico. They are dedicated to the preparation of secondary school teachers (escuelas secundarias) and the requirement for admission in most of them is a secondary school certificate and the degree of primary school teacher. Several of these schools offer the degree of "Licenciado" which takes about four years to complete.

Recently (1979) the Universidad Pedagógica Nacional was established, dedicated to the preparation of teachers. At present it has about 63 units throughout the country which include some of those previously known as "escuelas normales superiores."

The normal requirement for admission to the higher education level is the completion of the secondary and pre-university levels (preparatoria or equivalent). Many universities, such as the Universidad Autónoma Metropolitana, UAM (Metropolitan Autonomous University), and Universidad Nacional Autónoma require an entrance examination. This exam, in many cases, is not given to the students graduated from their "preparatorias" (pre-university schools attached to the university). Students enter this level at about 18 years of age.

Many observers consider that some schools at the tertiary level have low standards of admission, in particular in the case of technical schools and certain universities.

Physics Education at Primary and Secondary School Levels

Physics, as a discipline, is not offered in the primary school level (grades first through sixth) but certain aspects or topics are included in the courses in natural sciences taught at this level. A very significant step was taken during the late 70s, when a group of physics professors from the universities in Mexico were invited to participate in an inter-disciplinary group to prepare programs, textbooks, and teacher's manuals for the courses in the natural sciences at the primary school level. The literature in the sciences at this level is very limited. The preparation and training of teachers at this level remains one of the major problems in the educational system of Mexico.

At secondary school level (grades 7, 8, and 9), physics is offered as a discipline. It is normally taught two hours per week during the three years that comprise this level, but it varies with the institution. The textbooks used vary among the schools and they should be approved by the Secretary of Education. Typical Textbooks used include those by Alvaro Rincon, Arce, Rodriguez, Magaña-Velasco, and Virgilio Beltrán.

The physics teachers at this level frequently teach mathematics and chemistry in addition to the physics courses. It is also quite common to find engineers, physicians, and other professionals teaching physics without adequate knowledge of this discipline and/or without any special training or pedagogical preparation.

The laboratory equipment is inadequate in many schools, while in others it is practically absent. Less than 20% of the schools have adequate laboratory facilities.

According to some Mexican observers, teachers at this level are under serious economic, social, and bureaucratic problems.

It is worth mentioning that in certain small cities in Mexico, physics teachers are able to use materials developed in projects such as the UNESCO Pilot Project on Light as well as other laboratory-oriented activities.

Preparation of Secondary School Teachers in Physics

The preparation of physics teachers for this level takes place, officially, in the pedagogic centers described in the previous section as "escuelas normales superiores." The secondary school teachers are prepared using a very traditional format and their preparation in physics is very limited. The program normally required about four years of undergraduate work and, upon completion, the student normally receives the degree of Licenciado.

These pedagogic centers have had some other functions in addition to their regular programs including, for instance, short and intensive programs for secondary school physics teaching and regular training in physics teaching. The establishment of the Universidad Pedagógica Nacional was a positive step in trying to improve teacher's preparation. However, the data available on these centers indicates that the number of students enrolled in their programs has not increased according to the population growth and the need for well-trained teachers. Moreover, the dropout rate of students in these centers continues to be very high. Very few students complete the four-year program, increasing the population of poorly trained physics teachers at the secondary level.

Physics Education and Preparation of Physics Teachers at the Pre-University Level

The situation of physics education at the pre-university level is considered by many Mexicans to be in better shape than at the secondary level. Physics teachers are better prepared; however, the general curricula, contents, and level of the physics courses vary among the schools comprising these levels. There are hundreds of different programs among these schools. These programs vary according to the orientation of the schools (academic, technical, or vocational), and characteristics of the courses being offered (mandatory or optional), and to the university system that supervises or has some control on these schools.

For instance, in the "preparatorias" (senior high schools) attached to the National Autonomous University of Mexico (UNAM), physics is offered during the first semester of the three-year program four hours per week, using the textbook by Van DerMerwe as guidance. Another semester of physics is taught during the third semester. The most popular textbooks used in these courses are those written by Van DerMerwe and Dominguez.

In the "colegios de ciencias y humanidades" known as CCHs, another modality of the pre-university level also under the academic supervision of the National Autonomous University (UNAM), three courses of physics are offered. The first course is taught during the first semester. The textbooks used most often are those written by J. de Oyarzábal and another authored by Stollberg and Hill. During the fifth and sixth semesters of the three-year program, two more elective courses in physics are offered. Stollberg-Hill or Sears-White are the most popular textbooks. These courses are taught four hours per week during each semester.

The "colegio de bachilleres" includes three courses of physics in the three-year program. During the first semester a textbook written by F. Estrada is widely used. The second course is taught in the second semester using the textbook by Arthur Beiser, and the third semester is taught using Alonso-Finn. These three courses are offered four hours per week through each semester.

At the "colegios de educación en ciencias y tecnología" (oriented toward engineering and technology), which are under the supervision of the Instituto Politécnico Nacional, four semesters of physics are offered. The courses are taught six hours per week during the first four semesters of the three-year program (six semesters). The level of material covered is advanced and the textbooks used include Moreno y Mercado, Alonso-Finn, Sears-Zemanski, and Halliday-Resnick.

In the escuelas normales (primary school teacher preparation), only one semester of physics is offered. The course is taught three hours per week during the first semester of the three-year program (6 semesters). The textbooks used include those written by Dominguez and Van DerMerwe.

Laboratory work is very limited due to a lack of adequate laboratory facilities.

The preparation of the physics teachers at the pre-university level varies. It is possible to find teachers at this level with undergraduate and graduate degrees in physics from institutions of higher education (universities or the Instituto Politénico Nacional), but as in the secondary level it is possible to find teachers with degrees in engineering, chemistry, or other related professions. Furthermore, many undergraduate students, mainly from physics and engineering, are hired by the hour (part-time) to teach physics courses.

Most of the teachers, according to Mexican observers, do not have any pedagogical background. In fact, it is uncommon to find graduates from the Pedagogical Centers teaching at this level.

To improve this situation, teacher training programs and workshops have been offered to train physics students from the universities to teach at this level while they continue their undergraduate education.

Physics Education at the Higher Education Level

Physics plays an important role at this level. Introductory physics courses and, in many cases, advanced courses (upper division) are mandatory for students enrolled in different branches of engineering, computer sciences, and in programs in the biological and physical sciences (such as physics, chemistry, and biology). Other professional careers (medicine, architecture) also require some introductory physics courses.

The level and content of these courses vary according to the field selected by the student and the institution where it is offered. Many of the courses are offered through the physics department, but it is possible to find physics courses offered in the schools of engineering or medical schools independently of the physics department of the institution. This particular case is frequently found in the larger institutions such as the National Autonomous University (UNAM) and the National Polytechnic Institute (IPN).

The introductory physics courses (calculus-based) for students majoring in physics and certain brances of engineering (for instance, mechanical, electrical, and electronic engineering) are quite comparable to those offered in U.S. institutions. Typical textbooks used are Halliday-Resnick and Alonso-Finn. These textbooks are translated into Spanish. It is worth mentioning that for the past few years there has been an incipient movement to produce textbooks by Mexican authors.

There are other types of introductory courses offered at a lower level for students in biology, architecture, computer engineering, and medicine. For students enrolled in undergraduate degree programs in physics, the upper division courses include classical mechanics, electromagnetism, atomic and nuclear physics, quantum physics, etc.

In general, the curriculum for an undergraduate degree in physics in Mexico requires more course work than for a typical BS degree in U.S. institutions of higher education.

Table 4 shows the number of courses in physics taught at three of the major public institutions of higher education in Mexico City (Mexico D.F.), namely Universidad Nacional Autónoma de Mexico (UNAM), Universidad Autónoma Metropolitana (UAM), and Instituto Politénico Nacional (IPN) for students in some science and professional careers (excluding physics).

Table 4. Number of Courses in Physics Offered for Students in Some Careers in Science and Technology (Excluding Physics Majors) at UNAM (1983), UAM (1980), and IPN (1978).

Career	Institution	No. of Physics Courses	Level compared to courses offered for physics majors
Chemistry	UNAM	6	same
	UAM	6	same
	IPN (chemical engineering)	6	same
Engineering (Electronic, Mechanical, Electrical)	UNAM	7	lower
	UAM	7	lower
	IPN	7	lower
Biology	UNAM	2	lower
	UAM	4	lower
	IPN	3	lower
Medicine	UNAM	0	lower
	IPN	1	lower
Architecture	UNAM	2	lower
	UAM	2	lower
	IPN	4	lower
Computer Engineering	UNAM	3	lower
	UAM	5	lower
	IPN	0	

Some of these figures might be misleading because, for instance, the IPN offers introductory physics courses at a very high level during the pre-university level.

The level and content of the laboratory component of the physics courses vary among the different institutions. The physical facilities are also very different. They are, in general, better at the universities located in Mexico City than in others throughout the country.

Many of the undergraduate programs in physics in Mexico are quite acceptable according to international standards. In particular, those offered at the major universities in Mexico City, Puebla, Baja California, and Monterrey, to mention a few, are of excellent quality. The main problem with most of the undergraduate curricula in the Mexican institutions of higher education is the experimental component. According to some Mexican observers, the equipment and laboratory facilities in some institutions are very poor or nonexistent. However, during the past few years there have been enormous efforts from members of the faculty and some of the major institutions in Mexico City to improve the situation throughout the country.

During the early 60s teaching was not as rewarded as research in the major institutions of higher education in Mexico City. Instructors teaching physics courses were hired in most institutions by the hour and the main source of income was their research work in Institutes of Physics established in those institutions. The situation changed dramatically in the past few years, but still the research physicist received more recognition than the dedicated teacher. This situation is not very different from other countries including Europe and the United States.

The degree that a student receives upon completion of his/her undergraduate program varies according to the university awarding it. In most cases this degree is known as "Físico" (Physicist), but some institutions award the degree of "Licenciado." The first undergraduate degree from Mexican universities in some instances can be considered higher than a typical BS degree from U.S. institutions.

Table 5 shows some statistics related to a few Mexican institutions of higher education offering undergraduate degrees in physics.

The number of students enrolled in undergraduate physics programs has been steadily increasing since the late 60s. For instance, in 1970 there were only 44 students enrolled in both campuses (Azcapotzalco and Iztapalapa) of the Universidad Autónoma Metropolitana (UAM); in 1984 this number was about 305. In other programs in the basic sciences and engineering requiring physics courses, the enrollment went up from 509 in 1970 to 7,210 in 1984. In the Universidad Nacional Autónoma (UNAM) the enrollment has remained constant.

Graduate Programs in the Mexican Institutions of Higher Education

Graduate programs in physics have existed in some of the major institutions of higher education since the early 50s. In general, the graduate programs are of high quality by international standards. The Master's of Science and PhD programs require, in addition to graduate course work, the completion of an original thesis as is required in most U.S. institutions.

Table 5. Undergraduate Degree Programs and Enrollment of Students in Some of the Major Mexican Universities.

Institution and Location	Year the degree was established	Enrollment of Students				Graduates from the Indergraduate Program			
		1970	1975	1980	1984	1970	1975	1980	1984
Universidad Nacional Autónoma Facultad de Ciencias Mexico City	1938 (Physics) 1948 (Exp. Phys., Theor. Physics, Astronomy)	219	225	273		44	52	64	
Universidad Autónoma de Puebla Escuela de Ciencias Fisicas y Matemáticas, Puebla	1950 (Physics-Mathematics) 1972 (Physics)	47	147	428		0	2	5	
Universidad Autónoma de San Luis de Potosi Escuela de Fisica San Luis de Potosi	1956 (Physics) 1978 (Electronic Physics) 1982 (Theor. & Exp. Physics) 1982 (Math-Physics)	37	48	66		8	5	3	
Instituto Tecnológico de Monterrey Estudios Superiores de Monterrey Monterrey	1957 (Physical Science) 1964 (Physics-Mathematics) 1970 (Physics) 1980 (Indus. Eng.-Physics)	0	8	13		-	5	16	
Instituto Politecnico Nacional Escuela Superior de Fisica y Matematicas, Mexico City	1961 (Physics-Mathematics)	166	189	210		14	32	56	
Universidad Autónoma Metropolitana (Azcapotzalco) Mexico City	1974 (Physics-Engineering)	-	24	55		-	0	2	7
Universidad Autónoma Tetropolitana Iztapalapa Mexico City	1974 (Physics)	-	20	72	170	-	0	11	8

Table 6. Enrollment and Graduates with Master's Degrees from Some Mexican Universities (1970-1984).

Institution and Location	Year M.S. Programs were established	Enrollment of Students				Graduates from M.S. Program			
		1970	1975	1980	1984	1970	1975	1980	1984
Universidad Nacional Autónoma Facultad de Ciencias Mexico City	1955 (Physics) 1968 (Geophysics) 1975 (Radiation Physics) 1975 (Material Science) 1976 (Marine Sci.)	-	76	80	88	11	21	40	217
Instituto Politécnico Nacional Escuela Superior de Fisica y Matemáticas Mexico City	1961 (Nuclear Engineering) 1965 (Material Science) 1967 (Physics)	40	66	77	27	-	4	12	47
Centro de Investigación Científica y Educacion Superior Ensenada, Baja California	1972 (Geophysics) 1972 (Oceanography) 1973 (Electronics) 1976 (Optics) 1977 (Seismology)	-	5	39	3	-	-	14	
Univ. Autónoma de San Luis de Potosí Escuela de Fisica San Luis de Potosí	1974 (Physics	-	5	5	13	-	-	1	9
Universidad Autónoma Metropolitana-Iztapalapa Departamento de Ciencias Basicas e Ingenieria, Mexico City	1975 (Physics)	0	9	1	25	-	-	3	16
Universidad Autónoma de Puebla Escuela de Ciencias Fisicas y Matemáticas Puebla	1978 (Solid State Physics)	-	-	6	25	-	-	4	16

Table 7. Data Related to Some PhD Programs in Mexico (1970-1984).
There are other institutions located in different states but their programs were started in 1985.

Institution and Location	Year when the PhD was established	Enrollment of Students				Graduates w/PhD			Total No. Graduates to Date
		1970	1975	1980	1984	1970	1975	1980	
Universidad Nacional Autónoma Facultad de Ciencias Mexico City	1955 (Physics)	-	46	56	26	3	4	12	90
Instituto Politécnico Nacional (CINVESTAV) Mexico City	1962 (Physics)	4	6	10	19	-	1	2	22
Instituto Politécnico Nacional Escuela Superior de Fisica y Matemáticas Mexico City	1975 (Physics)	-	N/A	N/A	12	-	-	-	7

Table 6 shows some statistics related to the Master's program in physics.

There are several PhD programs in Mexico, but most of them are centralized at the major institutions located in Mexico City. Table 7 shows some data related to PhD programs housed in some of the universities in Mexico.

It is worth mentioning that there are other PhD programs that were started between 1982 and 1984 in institutions such as the Universidad Autónoma de Puebla and Universidad Autónoma Metropolitana-Iztapalapa (UAM), which offer a degree known as Doctor in Physics. Some other institutions such as the Universidad Autónoma de San Luis Potosi (San Luis Potosi) and the Centro de Investigación en Optica (Leon) have incipient PhD programs.

The qualifications of the faculty vary among the institutions. Many of them (PhD-granting institutions) require possession of the PhD degree or equivalent. Table 8 contains data about the faculty participating in graduate programs.

Table 8. Qualifications and Number of Faculty Members Working in Graduate Programs.

Type of Appointment	Qualifications	1980	1984
Full-time	with PhD	135	247
	without PhD	102	135
Part-time	with PhD	98	not available
	without PhD	108	not available

These figures might be misleading because many of the faculty members work at more than one institution.

Efforts to Improve Physics Education in Mexico

Many well-known physicists in Mexico had serious concerns about physics education during the early 60s. However, during those years only some sporadic efforts took place in this direction.

In the early 70s some physicists, in particular those returning with graduate degrees or from post-doctoral programs abroad, were stimulated to orient their work toward physics education. Others started research work groups in physics education at the local level. The continuous need for physics teachers at all levels, opening of new schools and departmentalization in the university, among others, were factors that contributed to the establishment of teacher training programs and groups working in the development of teaching materials, including construction of low-cost laboratory equipment.

Recently, under the sponsorship of the Ministry of Education (Under Secretary for Higher Education and Scientific Research), a program to update and prepare physics teachers was established. It is known as "Programa Nacional de Formación y Actualización de Profesores de Física." Workshops and courses on the use of computers in physics and the preparation of teaching materials have been offered.

The "Universidad Pedagógica Nacional" (National Pedagogic University) was founded in 1979 to prepare secondary school teachers and several Pedagogic Centers were established throughout the nation. Other programs offered during the late 70s included workshops, summer school conferences, and meetings organized by the "Sociedad Mexicana de Fisica" (Mexican Physical Society).

The "Consejo Nacional de Educación Tecnologica" (National Council for Technological Education), another office associated with the Ministry of Education, has been instrumental in the improvement of technological institutes throughout the country as well as in reviewing and improving the curriculum of the technical programs for the pre-university level.

Several journals or magazines are being published in Mexico oriented toward the improvement of teaching in general. Only a few of these journals or magazines are dedicated to science.

The Revista de la Sociedad Mexicana de Fisica (Journal of the Mexican Physical Society) used to publish an educational supplement for the benefit of teachers at all levels, in particular for those teaching at secondary and pre-university levels. Other journals for science teachers include Contactos (Contacts), Revista de Educación en Ciencias Basicas e Ingeniería (Journal of Education in Basic Science and Engineering), Ciencia y Desarrollo (Science and Development), and the Boletin del Centro de Ensenanza de la Fisica (Bulletin of the Center for Teaching Physics). Revista de la Facultad de Ciencias (Journal of the Faculty of Sciences) is also being published.

Some well-known Mexican physicists, still active in research, have been writing and continue to author modern and well-adapted textbooks in Spanish.

Mexican observers consider that while many projects are being established throughout the country, the preparation of professional physicists at the university level and the establishment of research groups in physics are still centralized in Mexico City. Another major concern in Mexico is that while the population continues to increase at a very high rate, the enrollment of students in physics has not increased accordingly except in very few instances.

It has also been found that the number of women studying and/or working in physics is small compared to those in other nations in the Western Hemisphere. Many of them work only part-time, but women who stay working in physics reach positions of prestige faster than men.

There have been several attempts in Mexico to develop research and doctoral programs in physics education, but opposition by the traditional academic world is very strong.

The Professional Physicist

The major occupation of the graduate with a degree in physics (undergraduate or graduate including PhDs) is still academically oriented. Research plays an important role in some of the major institutions of higher education. However, research groups are mainly located in institutions and centers in Mexico City.

Universities such as the "Universidad Nacional Autónoma de Mexico" (UNAM), the "Instituto Politénico Nacional" (IPN), and "Universidad Autónoma de Mexico" (UAM) have very strong research groups working in pure and applied research in physics. The Institute of Physics in the UNAM has received worldwide recognition for excellence in research in physics in several areas (theoretical and experimental). Scientists from all over the world have spent time there working with their Mexican colleagues. This is true also at the "Instituto Politénico Nacional" (IPN) and the "Universidad Autónoma Metropolitana."

The participation of physicists in private industry is still very limited. The private industry in Mexico is comprised of national companies and subsidiaries of international consortiums. In very few instances these industries are interested in research and development in physics, but the number of physicists working in industry is increasing. In addition, several Mexican physicists are working writing software for computers and in jobs on computations and information systems. Moreover, during the past few years there has been a transformation, and in other cases an establishment, of certain government-supported entities such as the "Instituto Mexicano del Petroleo" (Petroleum Mexican Institute), the "Instituto de Investigaciones Nucleares" (Institute for Nuclear Research, formerly known as the Nuclear Energy Commission), and the "Instituto de Investigaciones Electricas" (Electrical Research Institute) where an increasing number of Mexican physicists work in pure and applied areas of physics.

THE UNITED STATES OF AMERICA

General Information about the Country

The United States of America is a nation comprised mainly of a territory in the North American continent between Canada and Mexico extending from the Atlantic Ocean in the East to the Pacific in the West. It also includes Alaska to the northwest of Canada, Hawaii in the Central Pacific Ocean, and several other territories such as the Virgin Islands, several Pacific islands, and Puerto Rico. The total surface area of the United States of America is 9,372,614 km^2 or approximately 3,618,770 square miles, excluding the Great Lakes. The population according to estimates for 1987 is 243,773,000.

The country is a federal republic divided into 50 states and the District of Columbia where the capital, Washington D.C., is located. The Trust Territories of the Pacific Islands (Marshalls, Carolines, and the Marianas Islands), the Virgin Islands, and the Commonwealth of Puerto Rico are also part of the United States.

For historical and demographic reasons, the United States of America has been called a "melting-pot of races and cultures." The sparce indigenous population (American Indians) were rapidly outnumbered by waves of immigrants, first from Britain and then from other nations in Europe. In addition to descendants of the Europeans and a small minority of Native Americans, the population includes the following sizable ethnic minorities: Blacks, Hispanics from Latin America, and Asians.

The ethnic composition according to data available for 1986 was: white 84.8%, Black 12.1%, other ethnic groups 3.0%. The most significant immigration during the past few years is from Asian, Central and South American countries, and the Caribbean.

The age breakdown of the population (1986) was: under 15, 21.6%; 15 to 19, 25.4%; 30 to 44, 22.4%; 45 to 59, 13.9%; 60 to 74, 11.8%; 75 and over, 4.9%.

Table 1 shows the changing population in the United States of America between 1960 and 1985.

Table 1. Census Data for Population in Millions.

Age	Population in Millions			
	1960	1970	1980	1985
Less than 5 years	20.3	17.2	16.5	18.0
5 - 13 years	33.0	36.7	31.1	30.1
14 - 17 years	11.2	15.9	16.1	14.9
18 - 24 years	16.1	24.7	30.3	28.7
+ 24 years	130.1	110.6	133.8	147.6
Totals	180.7	205.1	227.8	239.3

The 1986 data also indicates that males comprise 48.68% of the population, while the percentage of females is larger and estimated at 51.32%.

The language is English but there are significant Spanish-speaking minorities.

The fundamental law of the United States is a constitution adopted in 1787 and since amended 26 times. Powers not reserved to the federal government by the constitution are retained by each of the 50 state governments, each having its own constitution.

The population in the United States of America has one of the highest income per capita in the world and enjoys high standards of living. The country is one of the world's leading powers. It is very rich in population, land, and natural resources. Moreover, the country is highly developed technologically. The economy is highly diversified and, while it has experienced heavy fluctuations since World War II, there has been an underlying trend of steady expansion.

The United States has vast mineral deposits of petroleum, natural gas, coal, copper, silver, and uranium. Important export industries include motor vehicles, aerospace industries, electronics, telecommunications, chemicals, steel, and all kinds of consumer goods.

Agriculture is highly mechanized, and modern techniques are used in obtaining high benefits from all the crops. Chief agricultural products among others are cereals, cotton, and tobacco.

In most materials the country is self-sufficient but still imports petroleum, chemicals, metals, machines, and vehicles, to mention a few.

Table 2 shows some economic data on the United States of America.

Table 2. Economic Data

	1970	1980	1984
Gross national product (GNP) in 10^9 (U.S. dollars)	993	2,632	3,663
Per capita income ($)	4,841	11,558	15,475
Disposable Personal Income	3,390	8,032	10,887
School Expenditures (10^9 $)	78.4	179.8	240.0
Per Capita Expenditure on Education	384	792	1,014
Percent of GNP spent on Education	7.9%	6.8%	6.6%

Literacy in the United States is very high. According to the data available for 1980, 95.5% of the total population age 15 and over was literate. This percentage might be higher at present. Males literate were 95.7% while figures for females indicate that 95.3% were literate. Functional literacy, the ability to use language effectively in everyday life, is not this high, however, according to some reports.

The Educational System in the United States of America

The educational system in the United States of America is highly decentralized. Most of the responsibility resides in the state and local governments, but the federal government normally helps them, providing supplementary funds to meet the needs of education at all levels.

The system of education can be considered divided into three main categories: a) primary level; b) secondary level; and c) higher education or tertiary level.

In general, the United States has been successful in providing 12 years of free schooling to its youngsters (primary and secondary schools) and ample opportunities to move on to the public and even to the private higher education level through scholarship programs and loans. The scholarship programs for the tertiary level are based on needs of the student and ability and desire to continue his/her education.

The federal government provides funds to support lunch programs in the primary and secondary schools, finances education for veterans, supports programs for schools and universities with large groups of minorities, provides funds for research and educational programs through the National Science Foundation and other organizations, administers education for Native American Indians, underwrites university and college student loans, etc.

Each of the 50 states, through its own department of education, has the responsibility of providing education at all levels, sometimes even at the higher education levels. These responsibilities vary among the states, but in general the department of education in each state establishes the curriculum, (particularly at primary and secondary level), graduation requirements, teacher certification or credentials, school finances and, in many cases, even working conditions for the school personnel.

However, the main responsibility for running the schools (primary and secondary level) resides in the counties or in small units called school districts. Funds for education come from local taxes. These districts are normally supervised by school boards which are directly elected by popular vote. In most cases a district superintendent is selected by the board to operate the school system at the primary and secondary level of education. The higher education system follows a different system that will be addressed later in this report.

The Primary and Secondary School Levels

The structure of the primary and secondary school levels is such that they must be considered together to obtain a better view of the educational system. Public education provided by each state consists of kindergarten plus 12 years of primary and secondary education. Because of the rapidly increasing number of working mothers, pre-kindergarten care (day care), which has an educational component, is provided in privately supported centers, occasionally in public-supported ones. The period of compulsory education varies among the states, but in general schooling is mandatory between the ages of 6 or 7 to 16.

There are different patterns for the primary and secondary level, depending on the location and the states, but the structures found most often are:

a) Kindergarten plus grades 1 through 8 for primary school, followed by four years of high school (grades 9 through 12).

b) Kindergarten plus grades 1 through 6 for primary school, followed by a three-year junior high school (grades 7, 8, 9) and three years of senior high school (grades 10, 11, 12).

c) Kindergarten plus grades 1 through 6, followed by two years of middle school (grades 7 and 8) and four years of high school (grades 9 through 12).

All these structures or patterns lead to a high school graduation at the age of 17 or 18.

It should be emphasized that only a few schools in the United States contain all the grades (often designated as K-12). In fact the schools are normally divided into primary schools, middle schools or junior high schools, and high schools.

The counties and/or school districts run the school system through the boards and district superintendents with professional staff. School boards have considerable autonomy within the guidelines established by each State Department of Education. These guidelines might include high school graduation requirements, school's curricula, and requirements for teachers' credentials. The daily administration of schools in the United States is done through about 16,200 local districts. Some of these districts might be comprised of a few schools (sometimes even one); others, in the large cities, have several schools and perhaps 800,000 students enrolled. More than 90% of all elementary and secondary school students attend public institutions. The majority of those attending private schools are in Catholic institutions.

According to the data for 1985, there were 26.9 million students enrolled in primary schools and 12.4 million in secondary schools. Expenditures on educational programs administered by the federal government were estimated at 18,398 millions (U.S. dollars).

The trend in the United States for the past few decades is to extend the number of years of formal schooling for students compared to past generations. Younger adults (25-29 years old) had more than 12.9 years of schooling on average. The elderly (75 years or above) spent about 9 years in school.

The dropouts through the system occur at about 16 years of age or after completion of the high school level when many youngsters decide to enter the work force. Major steps are being taken at the state and federal level to lower the dropout rate before completion of high school.

Special education is provided through the states with support from the federal government and private agencies for several millions of handicapped students. Special education services are established in many states for students with learning disabilities, the speech impaired, physically handicapped, emotionally disturbed, etc.

There is no official national curriculum for the elementary and secondary school levels in the United States. The departments of education in each state normally prescribe the curriculum for these levels, but there are always possibilities for the local districts and individuals to introduce variations. School administrators, subject specialists, and teachers are most of the time involved in the process of curriculum development.

Public interest groups and professors in the subject area in the universities and schools of education are also influential in curricular changes. Moreover, national organizations of teachers and some national testing agencies (such as the Educational Testing Service, a private, non-profit organization) always make contributions to provide considerable uniformity in the school system across the nation.

It should be mentioned that no matter which grades are included in a high school, there are usually two or three academic programs which students may select in consultation with full-time counselors. One of the options is a college or university preparatory program; another is a general program. Some high schools even provide a vocational program which prepares students for specific occupations as mechanics, office workers, or other similar types of jobs.

The primary and secondary system of instruction have been changing through the years influenced by history, geography, and demography of the country.

The traditional European curriculum used after independence was rapidly changed to account for unification of the country, teaching of North American values, and preparing the young for a productive life in a charging country. New subjects were incorporated, particularly at the secondary school level, with an increase in student's opportunities for choice.

Advances in technology during the 60s and 70s brought changes in teaching methods, individualized instruction, use of television, computer-aided instruction, ethnic studies, etc.

During the past few years, there have been serious concerns about the quality of school performance and its relation to career opportunities. The proposals for reform have been focused on raising standards of achievements at all levels from basic school (primary level) to high school graduation. A strong movement to strengthen the curriculum, especially in mathematics, science, and foreign language is underway in several states. Also, improving teacher preparation and performance has become a very important issue and positive steps are being taken in that direction.

Involvement of the states in the educational process has been increasing. Most of the states are setting criteria for the high school diploma in the form of minimum competency requirements. Several states, through the local districts, are establishing tests to assess students' competency for graduation, particularly in reading, writing, mathematics, and the sciences. The Federal Government has been making periodic announcements and reports about average achievement levels at the primary and secondary levels in an effort to influence local districts and states to improve the quality of education.

In general the teachers at primary and secondary level are better educated at present than they were several years ago. The majority of them have the appropriate degree and credentials. Most of the teachers at these levels are females (about 78% at primary school level and about 50% at secondary school level), but the number of males selecting teaching as a profesison has been increasing, particularly at secondary school level.

Funding for the operation of the primary and secondary schools in the United States is obtained mainly from local sources (counties, cities) in the form of real estate taxes, and from state taxes. However, a large portion of the public school revenues are provided by federal funds, especially in poorer regions of the nation. Table 3 contains general data about the primary and secondary school levels.

Table 3. Statistical Data on the Primary and Secondary School Level of Instruction. Source: Brittanica Encyclopedia (Yearbook 1987).

	Total No. of Schools	Teachers	Students	Student/ Teacher Ratio
Pre-Primary and Primary (ages 5 - 12)	101,050	1,469,000	31,555,000	21.5
Secondary and Vocational Schools (ages 14-17)		1,061,000	13,703,000	12.9

Higher Education System in the United States

The tertiary or higher education level in the United States is mainly comprised of three types of institutions: a) colleges, b) universities, and c) community colleges (also known as junior colleges or two-year colleges) and technical colleges.

Colleges and Universities

There are certain differences between colleges and universities even though both are degree-granting institutions. The colleges, often called liberal arts colleges, mainly offer four-year courses of study leading to a Bachelor's degree (Bachelor of Arts or Bachelor of Science). However, in many cases these colleges also offer graduate programs, including Master's and PhD degrees in several disciplines.

The universities are comprised of a liberal arts college, where students can receive undergraduate and graduate degrees, and one or more professional schools such as engineering, education, medicine, pharmacy, etc., where students can obtain professional degrees in engineering, medicine, teaching credentials, etc.

The liberal arts colleges serve a double purpose because in most of the universities they are in charge of the introductory courses in the sciences, humanities, and social sciences required for a professional degree. In many cases the universities offer, in addition to their corresponding undergraduate programs, Master's and PhD programs in the liberal arts (physics, chemistry, social sciences, etc) and in professional areas such as engineering, education, and pharmacy to mention a few.

The colleges and universities in the United States are characterized by the flexibility of their programs. A student, upon admission to one of these institutions, does not have to declare a specific area of concentration. Many of them formally declare the subject on which they wish to concentrate between their second (sophomore) and third (junior) years.

According to the data available for 1986-87, there are 3280 institutions of higher education in the United States, with about 690,000 faculty members and 12,164,000 students enrolled. The student/teacher ratio was approximately 17.6. These institutions can be private or public (state-supported).

One characteristic of the colleges and universities in the United States is that the majority of them have dormitory facilities for the students. A large proportion of the students attending these institutions reside on the campus or school grounds, creating a special atmosphere for student life. In fact, in many of these institutions of higher education it is mandatory for undergraduates to live on campus for a certain period of time, particularly during the first (freshman) and second (sophomore) years of their enrollment.

The structure as well as the governing body for colleges and universities varies according to the region or state where they are located and on whether they are private or public institutions. In the case of public colleges and universities, most of the states have a board of regents responsible for the higher educational system. In many cases this board is also responsible for the licensing of private colleges and universities. Each private institution has its own board of trustees or board of regents which governs the college or university.

Higher education institutions are managed by a president or chancellor appointed by the board of trustees with input, in many cases, by faculty and administrator committees. In addition, colleges and universities appoint deans and/or administrative staff responsible for administrative and financial matters. The selection process of these administrators varies among the different institutions.

The major responsibility for the educational programs and selection of the academic staff resides in the faculty.

Colleges and universities are normally subject to review process by accrediting organizations comprised of colleges and universities in the region.

Admission to Colleges and Universities

The requirements for admissions vary among the colleges and universities. While in the public institutions it might be established by the higher education state boards, each private institution sets its own admission standards. In general, students must possess a high school diploma, but their preparation should be college oriented (academic track) rather than a general basic high school. Standards, however, vary because of the absence of any national public examination and of consistency among examination systems offered by some states. Thus, many colleges and universities rely heavily on tests given to future college students by two organizations: The Educational Testing Service and the American College Testing Program.

The test results most often used by Colleges and Universities for admission decisions of undergraduates are the Scholastic Aptitude Test (SAT) and the American College Test (ACT). These tests attempt to measure pre-college skill attainment and contain verbal and mathematics aptitude tests.

Undergraduate Curriculum

The curriculum for the first undergraduate degree (Bachelor of Arts or Bachelor of Science) varies among the colleges and universities in the United States. In most cases it is recommended by the faculty, subject to the approval of the administration and recommendations of the accrediting organizations (national or regional). Normally, the Bachelor of Arts (BA) degree includes a broader number of courses to guarantee general preparation. The Bachelor of Science (BS) degree might include more concentration in a particular field requiring more courses in the subject selected by the student. Usually, the BA or BS degree from an accredited college requires four years of course work. However, in the case of a professional degree such as a BS in Engineering, it might require five years to complete. Some schools of engineering in the universities include a mandatory one year of work in industry (cooperative education) before the student is awarded the BS degree.

In the case of law, medicine, veterinary, or dental schools, students must be in possession of a Bachelor's degree and pass an examination before they are admitted. Moreover, the number of students accepted to these professional schools is limited. The degree usually takes about four years in addition to their undergraduate education. Consequently these professional degrees are considered graduate programs.

Graduate Programs

Some colleges and universities, both public and private, offer graduate programs in several subject areas and fields. The students must be in possession of a Bachelor's degree and in most institutions they are required to take the Graduate Record Examination (GRE) and submit it with their application. The graduate school and/or a committee for graduate students comprised of faculty and administrators make the decision of accepting or denying admission to graduate work.

The typical graduate programs offered by most of the institutions are the Master's and PhD degrees. However, the schools of education offer other types of degrees such as Educational Doctors (EdD) and Specialists in Education. The schools of pharmacy also offer degrees such as Doctor in Pharmacy in addition to the PhD programs.

Finances in Colleges and Universities

Public institutions are funded by state governments and the federal government, but a proportion of their revenues come from student's tuition, fees, etc. Thus, the student or the family of the study pays a portion of his/her undergraduate education.

Private institutions are mainly funded by tuition, gifts, donations, and endowments. The undergraduate student pays, in general, higher tuition and fees in private colleges and universities. In many cases tuition provides the major income or source of revenues for these institutions. In many states students applying and admitted to private institutions can obtain scholarships from the state and federal government to defray expenses. These scholarships are normally based on the economic needs of the student and academic record.

The federal government also helps public and private institutions through grants, low-cost student loans, etc.

Students in graduate programs can usually obtain tuition-free schooling and many of them work part-time for the department in which they are enrolled as a teaching or research assistant.

Tuition and living costs in colleges and universities have been increasing sharply during the past few years.

Community Colleges (Junior Colleges) and Technical Schools

The community colleges, which have become very popular during the past few years, offer two-year programs in a variety of fields. In many cases the two-year course work leads to what is known as an Associate of Arts Degree. Students, through advising, can transfer to four-year colleges and universities upon acceptance of their course work.

The requirements for admission are lower than those for four-year colleges and universities. In many of the community colleges, there is an open policy of admissions. In addition many students who have not completed their high school can enroll in special courses to complete their secondary education or obtain some skills to enter the work force directly.

The two-year colleges also offer technical and vocational courses of study. Many of these institutions prepare electricians, certified plumbers, automotive bodywork technicians, mechanics, and other skilled workers.

The community or junior colleges can be public or private. The public system is, in general, inexpensive and funded through the state and local communities. They have their own board of trustees, president, and staff to manage them.

The technical colleges or technical institutes are another interesting modality of the educational system in the United States. There are a wide variety of them fulfilling different needs for a modern society. Many of them prepare highly skilled technicians to fill the gap between the regular worker and the professional scientist or engineer. Some of these technical colleges even offer three- and four-year degrees and are accredited through the Accreditation Board of Engineering and Technology. They have a qualified faculty and excellent programs.

There are other technical colleges (mainly private) dedicated to the preparation of students in areas such as word processing, computer programmers, medical technology, beauty salon operators, etc. These institutions offer skill courses which vary in duration from six months to one or one and a half years.

Physics Education at the Primary and Secondary Level

The highly decentralized system of education in the United States has been considered one of its weaknesses because, as noted earlier, there is no national curriculum. However, it is also one of its strengths. The system has provided great opportunities for the implementaion of innovative ideas and varied practices. The diversity of the system makes it very difficult to understand and to interpret studies on any specific area, particularly in physics education.

At the primary school level (grades K-6), children are often exposed to topics in the sciences, but physics, as a discipline, is not offered. Some school districts include general science courses, but primary school teachers tend to avoid these topics. In most cases the courses in the sciences are oriented toward simple aspects of the biological sciences and serious laboratory-oriented activities seldom have been offered.

During the seventh and eighth grades, some courses are offered in physical science (about 50% of the contents is basic physics), but due to the flexibility of the curriculum, students postpone or avoid taking them until the ninth grade or first year in high school. In many cases, it has been found that this is the only course with some physics content that students take during high school.

Physics, as a separate subject matter, is offered as a one-year course by most high schools in the United States, but many students receive their high school diploma without ever taking a physics course. Physics courses offered at secondary school level vary in content, methodology of teaching, level of instruction, quality, and even with the size of the shcool, region of the United States where the school district is located, and demographic character of the student body.

The most recent survey conducted by the American Institute of Physics (AIP) in 1986-87 (Survey of Secondary School Teachers of Physics) and prepared by Michael Newschatz and Maude Covalt, provides a wealth of information on physics education in the United States at the high school level. Most of the data in this work was taken from the AIP report, thanks to the generosity of the authors.

A typical physics course will meet for 50 minutes, five times a week. A student who follows a college preparatory track in high school normally takes a general science or physical science course in the eighth or ninth grade and a physics course in the twelth grade.

In the larger high schools, there would be a choice of physics courses. It is possible to find introductory-level courses, honor courses, and even advanced placement courses with the level of the calculus-based physics offered in colleges and universities across the nation. The less advanced would use a non-mathematical text written especially for high schools.

The AIP report--based on a survey of 3478 high school representatives of 21,700 public, Catholic, and private schools across the nation--shows that only about 20% of all high school graduates take physics as a discipline. The figure is relative low for a highly industrialized nation interested in maintaining a well-trained and scientifically literate population. Table 4 shows some figures related to the survey of 3478 schools.

Table 4. Physics Enrollments by Course. Source: AIP Report (1986-87).

	Total-all types of physics	Regular first year	Honors	AP	Second year	Physics for non-science students	Other types of physics
No. of classes	35,200	28,200 (80%)	3,500 (10%)	1,400 (4%)	500 (1%)	1,400 (4%)	200 (1%)
No. of students	623,600	497,800 (80%)	70,500 (11%)	19,000 (3%)	6,200 (1%)	24,000 (4%)	3,400 (1%)
Average class size	18	18	20	14	12	17	17

It is worth mentioning that about one third of the public school teachers report an increase in the proportion of students taking physics over the past five years, while fewer than one in ten report a decline. The increase in physics enrollment might be due to a trend across the nation toward raising requirements for high school graduation.

The frequency and variety of physics course offerings is normally related to the size of the school. Small, rural public high schools and private schools with a fundamentalist religious orientation are least likely to include physics in their curriculum. Larger schools normally offer more physics courses than smaller schools, but there is a slight tendency for the larger public schools to have a lower proportion of students enrolled in physics than smaller schools. About two thirds of all high schools in the nation offer physics every year, and another 17% offer the course in alternate years. Well-informed observers consider that only 7% of the schools offer more than three sections of physics. The AIP report shows that 96% of all high school students attend schools where physics is taught.

In general, schools offering advanced physics classes (second-year physics) enrolled a higher proportion of students in the basic first-year course as well.

According to the results of the AIP survey (1986-87), there were 17,900 teachers with physics assignments, teaching about 35,200 physics classes in the 15,800 high schools offering at least one course in physics. In other findings of the survey, 90% of all public high schools have only one physics teacher and 82% offer only the basic first-year course in physics.

Those public schools in which the enrollment is predominantly composed of minorities (mainly Blacks and Hispanics) enroll a smaller number of seniors in physics. There are, however, a fair number of smaller high schools in the South and Pacific regions of the United States with large minority enrollments which seem well-positioned to offer an extensive program in physcis. Also, the students have a greater choice of physics-related extracurricular activities.

In analyzing the profile of the high school physics teachers in public schools, it has been found that most of them are males (more than three fourths) with female teachers concentrated in smaller schools and private schools.

In general, physics teachers spend only about one third of their time teaching physics. The rest of their time is used to teach other subjects such as chemistry, earth science, mathematics, and general and physical science. The AIP survey (1986-87) indicates that only 13% of the responding teachers had teaching assignments in physics alone in 1987.

Almost all the teachers in the high schools are in possession of the Bachelor's degree (BA or BS) plus the appropriate credential. In fact, almost two thirds of those teaching physics held graduate degrees, but only about one fourth of the teachers earned a degree in physics. However, those teachers without physics degrees have taken some college courses in the field. Teachers with a physics degree tend to concentrate in the larger schools.

Many of the physics teachers without formal training in physics have acquired their experience through years of teaching, teacher training workshops, and/or summer seminars in physics.

In some states and/or regions of the United States, teachers are not certified in a particular subject area. For instance, a credential in the physical sciences in California will allow them to teach physics, chemistry, and earth sciences.

Table 5 shows the results of the AIP survey on objectives stressed in physics courses at the high school level.

Table 5. Objectives Stressed in Physics Teaching. Source: AIP Report (1986-87).

Objectives	Ranking among top 3 (%)	Highest rank (%)
Teaching basic physical concepts	74	37
Developing general problem-solving abilities	78	36
Teaching analytical/mathematical skills	43	11
Showing how physics operates in everday life	38	6
Covering the material necessary to prepare students for future coursework in physics	26	6
Teaching laboratory skills	19	1
Motivating students to continue physics studies	7	1
Preparing students for advanced placement tests	2	*
Teaching computer skills	1	*

*less than one-half percent.

Teachers have, in general, great influence in the selection of textbooks and the type of physics courses offered at their schools. There is a great variety of physics textbooks used in the high schools. Table 6 provides some statistics on textbook use and ratings.

Table 6. Physics Textbook Use and Ratings. Source: AIP Report (1986-87).

Name of Text	Teachers With This Course Using Text (&)	Mean Quality Rating (1 = poor, 5 = excellent)
Regular first-year:		
1. Modern Physics (Williams et at.)	36	3.7
2. Physics: Principles & Problems (Murphy et al.)	33	3.6
3. Physics: Its Methods & Meanings (Taffel)	7	3.6
4. PSSC Physics (Haber-Schaim et al.)	5	3.6
5. Project Physics (Rutherford et al.)	5	3.5
Honors:		
1. Modern Physics (Williams et al.)	28	3.7
2. PSSC Physics (Haber-Schaim et al.)	24	3.6
3. Physics (Giancoli)	7	4.3
4. Physics: Principles & Problems (Murphy et al.)	7	3.3
5. Physics: Its Methods & Meanings (Taffel)	6	3.8
Advanced Placement:		
1. University Physics (Sears et al.)	21	4.3
2. Fundamentals of Physics (Halliday & Resnick)	20	4.5
3. Physics (Giancoli)	9	4.2
4. College Physics (Miller et al.)	8	4.3
5. College Physics (Sears & Zemanski)	7	4.3
Second Year:		
1. Physics (Gaincoli)	31	4.3
2. Modern Physics (Williams et al.)	12	4.4
3. University Physics (Sears et al.)	11	3.6
4. Fundamentals of Physics (Halliday & Resnick)	10	4.4
5. College Physics (Sears & Zemanski)	10	4.8
Physics for Non-science Students:		
1. Physics: Principles & Problems (Murphy et al.)	28	3.3
2. Conceptual Physics (Hewitt)	27	4.5
3. Project Physics (Rutherford et al.)	12	2.8
4. Modern Physics (Williams et al.)	8	4.0
5. Physics: Its Meanings & Methods (Taffel)	4	2.8

There are several journals published in the United States on physics education, physics and science education, and general interest science. The most widely read are Discover and Scientific American. The most helpful in the classroom, according to high school physics teachers, is The Physics Teacher put out by the American Association of Physics Teachers. Other journals used by physics teachers are Physics Today, Science, The Science Teacher, and Science News.

Table 7 shows the affiliation of high school teachers with professional organizations.

Table 7. Affiliation with and Level of Activity in Professional Organizations. Source: AIP Report (1986-87).

Organization	Affiliated (%)	Inactive (%)	Somewhat Active (%)	Very Active (%)
National Education Assn.	39	45	45	10
Natl. Science Teachers Assn.	30	53	41	6
American Assn. of Physics Teachers	24	44	47	9
Natl. Council of Teachers of Mathematics	8	51	43	6
American Chemical Society	6	48	47	5
American Federation of Teachers	6	46	38	16
Other Professional Organizations	24	--	--	--

Many private industries, national laboratories, and research institutions are offering new possibilities for the high school physics teacher to improve and update his/her knowledge of physics and related fields.

Physics teachers at this level still consider that they are underpaid compared to other professionals in different fields. They also believe that they do not have enough time for class preparation and the funds marked for laboratory, supplies, and new equipment are not appropriate. These remarks are similar to those stated by teachers in other countries of the Western Hemisphere.

Physics Education at the College or University Level

Physics, as a discipline, plays an important role in the education of students in colleges and universities in the United States. In general, professors and/or teachers in this discipline are highly respected across the nation. The subject is normally taught as a fundamental discipline and it is almost impossible to find an institution of higher education in which physics or physics-related courses are not offered.

Most of the institutions of higher education have a physics department or school of physics. There are some small institutions, particularly those that do not offer a specialization or major in physics, where the faculty in this discipline is grouped in science or physical science departments. The size of the department varies among the institutions. Some might consist of only one to three faculty members while in other large universities they could have 80 or more members. In general, institutions that offer only the Bachelor's degree (liberal arts colleges) are primarily oriented toward teaching (including student participation in faculty research). PhD-granting institutions emphasize research and graduate teaching although not to the exclusion of interest in undergraduate teaching.

The basic undergraduate degree is the Bachelor's degree. Many institutions in the United States offer a Bachelor of Arts (BA) and Bachelor of Science (BS) degree. The BA degree normally places a higher emphasis on general education courses (humanities and social sciences). However, several of the 4-year liberal arts colleges offer only a Bachelor of Arts degree which includes a well-balanced preparation in physics, mathematics, and social sciences, and humanities.

The undergraduate curriculum for physics majors varies among the colleges and universities. The large institutions are able to offer a wide variety of elective courses in physics. In general, the preparation of physics majors includes two or three semesters of introductory calculus-based physics and courses in modern physics (atomic and nuclear), advanced laboratory, thermodynamics or statistical physics, electromagnetism (electrostatics and electrodynamics), theoretical mechanics, quantum physics, courses in condensed matter physics, and other elective courses depending on the institution.

The Master's degree is, after the Bachelor's degree, the next higher degree which can be obtained. It usually takes about a year or a year and a half. Some students obtain a Master's degree as a terminal degree, while others continue to complete their doctor or PhD degree.

The PhD degree takes an average of 5.4 years to obtain after the Bachelor's degree and is the highest degree a student can receive. Most of the research physicists (particularly in academic institutions) and faculty members in universities and colleges hold the PhD degree. About 50% of new PhD recipients spend one or two years as postdoctoral students in temporary research jobs.

Physics enrollments and degrees have been monitored since 1960 by the American Institute of Physics. The Survey of Enrollments and Degrees was expanded since the mid-1970s to include data on astronomy degrees.

Table 8 classifies institutions according to the highest physics degree granted. The table also presents yearly changes in those numbers since 1982.

Table 8. Institutions by Highest Physics Degree Offered in the United States, 1982-87. Source: American Institute of Physics Report (AIP Pub. No. R-151.24, June 1987).

Academic Year	Doctoral granting*	Master's granting	Bachelor's granting
1982-83	164	94	488
1983-84	165	92	490
1984-85	168	90	487
1985-86	168	91	485
1986-87	168	90	496

*Four of these institutions have two physics doctorate-granting departments. They are Stanford U., U. of CA-Davis, Harvard U., and Cornell U.

Figure 1 presents the physics degree production and trends between 1975-1986. Table 9 shows the physics enrollment, undergraduate and graduate, and degrees awarded by academic year 1975-1987.

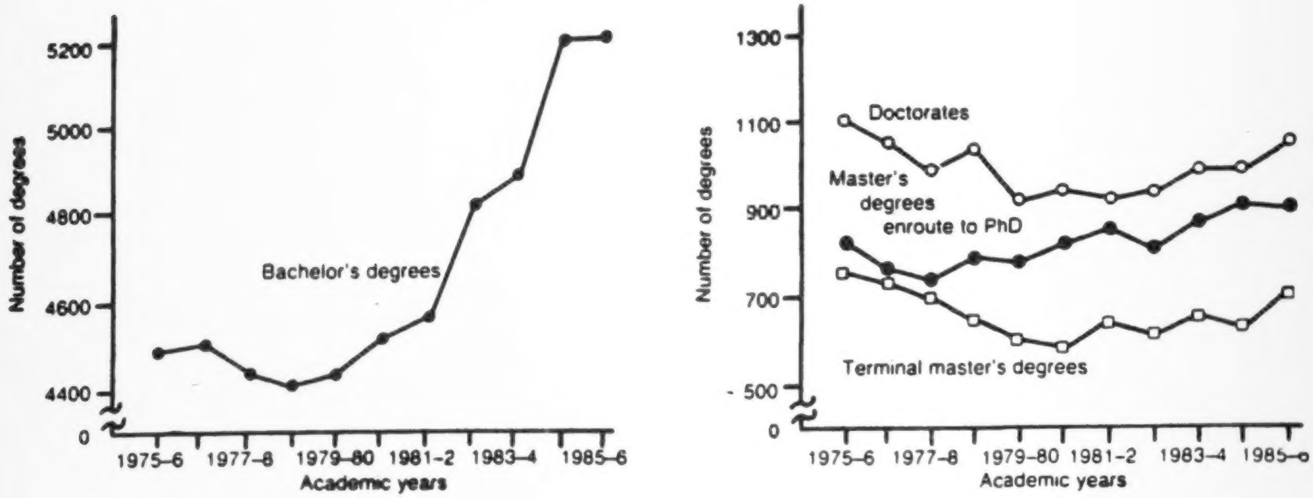


Fig. 1. Physics degrees awarded by academic year, 1975-86. Source: AIP Report (Pub. R. 151.24).

Table 9. Physics Enrollments and Degrees Awarded by Academic Year, 1975-1987. Source: AIP Report (Pub. R. 151.24).

Academic year	Number of physics degrees granted (July 1 to June 30)			Undergraduate physics major enrollments		Graduate physics student enrollments*	
	Bachelor's	Master's	Doctor's	Juniors	Seniors	Total	1st year
1975–76	4487	1570	1111	5888	4922†	10 372	2646
1976–77	4517	1469	1051	5711	4930†	9 991	2624
1977–78	4457	1422	971	5820	4975††	9 835	2499
1978–79	4416	1428	1033	5835	4964	9 813	2458
1979–80	4440	1370	912	5696	4942	9 647	2439
1980–81	4513	1387	927	5905	5091	9 934	2564
1981–82	4558	1476	912	6386	5372	10 173	2637
1982–83	4795	1426	921	6299	5580	10 429	2630
1983–84	4878	1521	971	6303	5658	10 922	2855
1984–85	5188	1518	972	6601	6009	11 337	2863
1985–86	5214	1589	1051	6689	6092	12 011	2981
1986–87				6592	6119	12 616	3162

**Includes part-time students.*
†This total has been adjusted by 500 students who were seniors for more than one year.
††This total has been adjusted by 300 students who were seniors for more than one year.

Every physics department gives courses designed as service courses for other departments and specialties. These courses vary in length, from one semester to a full-year course. They might include general physics, physical science, physics for biologists, astronomy, etc. These type of introductory courses constitute an important teaching load for faculty members. The larger institutions offer several introductory physics courses each term. The total enrollment at this level including physics majors (fewer than 9,000) comes close to 300,000.

There is a large variety of textbooks written for introductory physics courses in the United States. The number of textbooks for the calculus-based physics courses has grown considerably. It is also expected that after the Commission on University Introductory Physics Courses makes recommendations, new textbooks with new dimensions will appear.

Table 10 shows the enrollment in introductory physics courses during 1986-87.

Table 10. Introductory Physics Enrollments, 1986-87. Source: AIP Report (R-151.24).

Enrollment in introductory physics courses designed for:		Institution type						Total	
		Bachelor's granting		Master's granting		Doctorate granting			
		N	%	N	%	N	%	N	%
Engineering majors		20 900	30.0	13 250	33.0	73 650	44.6	107 800	39.2
Physical science majors		18 700	26.8	9 200	22.9	30 950	18.7	58 850	21.4
Biology, health-related majors		18 450	26.5	9 400	23.4	38 700	23.4	66 550	24.2
Other		11 700	16.8	8 300	20.7	21 800	13.2	41 800	15.2
Total introductory enrollment	N	69 750		40 150		165 100		275 000	
	%		25.4		14.6		60.0		100%

The attrition of physics majors in the three types of institutions (Doctorate-, Master's, and Bachelor's-granting) in the United States is relatively constant. The following table indicates the attrition rates during 1976-77 to 1985-86.

Table 11. Attrition of Undergraduate Physics Majors by Type of Institution, 1976-77 to 1985-86. Source: AIP Report (R-151.24).

Graduating class	Doctorate granting institution		Master's granting institution		Bachelor's granting institution	
	No. of freshman	% reaching sr. year	No. of freshman	% reaching sr. year	No. of freshman	% reaching sr. year
1980	3450	74%	1110	60%	3200	56%
1981	3520	73	1070	63	3310	57
1982	3590	73	1140	63	3410	59
1983	3770	72	1160	63	3510	60
1984	3890	74	1250	60	3550	60
1985	3940	75	1160	68	3560	60
1986	3930	78	1170	69	3570	61

Several interesting phenomena have been taking place over the past few years. The undergraduate enrollment is shifting from private to public institutions and a large percentage of the Bachelor's degree recipients (U.S. citizens) are going directly to work in industry. Moreover, the military service has become the fastest-growing employment category for new physics bachelors, although the total numbers are not large. Table 12 indicates trends for graduating classes of physics bachelors from 1977-1987.

Table 12. Trends for Graduating Classes of Physics Bachelors, 1977-1987.

Postbaccalaureate plans	1977-78	1978-79	1979-80	1980-81	1981-82	1982-83	1983-84	1984-85	1985-86	1986-87
Physics graduate study	33%	31%	30%	29%	30%	30%	30%	29%	28%	29%
Other graduate study	26	24	24	24	23	24	22	21	21	22
Civilian employment	34	38	38	39	38	36	40	43	43	39
Military service	5	5	5	6	7	8	6	5	6	7
Undecided	2	2	3	2	2	2	2	2	2	3
Total number of physics bachelor's degrees	4457	4416	4440	4513	4558	4795	4878	5188	5214	5253

There are interesting differences among the new bachelor's degree graduates, as shown in Table 13.

Table 13. Characteristics of New Physics Bachelors, 1986-87. Source: AIP Report (Pub. R-207.19).

		Postbaccalaureate plans				
		Graduate study				
Characteristics		Physics	Other	Employment	Undecided	Total
Sex	Female*	13%	19%	16%	17%	16.1%
	Male	87	81	84	83	83.9
Citizenship	U.S.	92%	94%	97%	92%	94.9%
	Foreign	8	6	3	8	5.1
Age	20 or younger	1%	1%	-	-	0.6%
	21	6	3	3%	8%	4.1
	22	47	48	36	39	42.1
	23	21	27	24	18	23.4
	24-27	16	15	23	22	18.6
	28 or older	9	6	14	13	11.2
Minority groups	U.S. blacks	1.8%	1.5%	2.4%	4.5%	2.1%
	Other U.S. minor.	6.7	5.8	5.7	7.9	6.1
	Foreign minor.	6.2	4.5	1.7	6.8	3.8
Transferred from junior college	Yes	9%	5%	12%	16%	9.7%
	No	91	95	88	79	90.3
Double major	Yes	27%	38%	25%	21%	29.0%
	No	73	62	75	79	71.0
Type of undergraduate institution	Public	59%	50%	65%	56%	60.0%
	Private	41	50	35	44	40.0
	PhD-granting	55%	46%	43%	43%	47.1%
	MS-granting	12	9	14	10	12.5
	BS/BA-granting	33	45	43	47	40.4
Total number of bachelors		1545	1132	2411	165	5253
% distribution		29%	22%	46%	3%	100%
Number of respondents		824	604	1286	88	2802

**Percentage of women was adjusted for differential response rate.*

Those employment-oriented physics bachelors include the lowest proportion of foreign graduates; they are older and are more likely to have transferred from a junior college to the college or university.

In the past, most of the recipients of a Bachelor's degree would try to continue graduate work to become a physicist. A new trend of postponing or ignoring graduate work has increased in popularity over the decades. Unfortunately, most of the students graduating with a Bachelor's degree were trained for graduate work. Some changes are taking place in many institutions including encouraging students to seek summer work in industry, placing more emphasis in undergraduate research, and so on. Table 14 contains interesting data about full-time employment of new physics bachelors (1987).

Table 14. Full-Time Employment* of New Physics Bachelors, 1987. Source: AIP Report (Pub. R-211.19).

Work activity		Type of employer							Total	
		Industry		High school	Government		Coll. univ.	Other		
		manufacture	service		civilian	military			N	%
Teaching		-	-	33	11	-	5	1	50	7%
Research & development		40	11	1	16	87	19	3	177	24
Development & design		133	29	-	26	6	7	2	203	28
Programming		29	37	-	16	3	5	1	91	12
Specialized training**		3	7	-	4	85	1	-	100	14
Marketing		8	13	-	1	-	-	-	22	3
Other professional work		7	28	-	3	3	4	6	51	7
Other		10	23	-	4	1	1	-	39	5
Total	**N**	230	148	34	81	185	42	13	733	
	%	31	20	5	11	25	6	2		100%
Using physics training	**Yes**	93%	53%	100%	92%	90%	95%	73%		83%
	No	7	47	-	8	10	5	27		17

**The employment of these 733 graduates includes both newly accepted positions as well as those in which graduates are continuing. Excluded are graduates in temporary and summer employment.*

***Training paid for by the employer includes pilot navigator training by the military.*

Graduate Enrollment at U.S. Institutions of Higher Education

Following a ten-year decline in the graduate physics enrollment, 1980 started an upward trend which has continued for the past six years. However, it was the foreign students who caused this change in trend. Since 1980, the number of graduate students has increased by 25%, and the educational backgrounds of the students have become increasingly diverse. Table 15 shows the graduate physics enrollment between 1977-1987.

Table 15. Full-Time, Part-Time, and Foreign Graduate Physics Enrollment by Type of Institution, 1977-1987. Source: AIP Report (Pub. R-151.24).

Academic year	Graduate students at doctorate granting institution					Graduate students at master's granting institution				
	Full-time	Part-time	Foreign	% foreign of total	Total	Full-time	Part-time	Foreign	% foreign of total	Total
1977-78	8 174	678	2 061	23.3	8 852	546	437	128	13.0	983
1978-79	8 185	679	2 175	24.5	8 864	468	481	157	16.5	949
1979-80	8 059	685	2 390	27.3	8 744	550	353	146	16.2	903
1980-81	8 302	760	2 540	28.0	9 062	484	388	163	18.7	872
1981-82	8 555	718	2 894	31.2	9 273	543	357	213	23.7	900
1982-83	8 712	812	3 193	33.5	9 524	566	339	221	24.4	905
1983-84	9 285	721	3 433	34.3	10 006	569	347	254	27.7	916
1984-85	9 647	710	3 811	36.8	10 357	604	376	293	29.9	980
1985-86	10 119	818	4 259	38.9	10 937	620	454	306	28.5	1074
1986-87	10 583	851	4 519	39.7	11 389	772	455	397	32.4	1227

The trend in entering graduate physics students in U.S. institutions is shown in Table 16. It should be noticed that in 1977 one out of four graduate students was foreign; in 1986-87, two out of five students were foreign. The AIP Report (Pub. No. R-207-19, 1987) on a Survey of Graduate Students in Physics indicates that 38% are foreign students. The report also concludes that fewer foreign doctorate recipients were able to secure permanent employment in the United States.

Table 16. Trend in Entering U.S. and Foreign Graduate Physics Students, 1977-1987. Source: AIP Report (Pub. R-151.24).

Academic year	No. of first-year graduate students U.S.	Foreign	Total	% foreign students of total
1977-78	1851	648	2499	26.0
1978-79	1840	618	2458	25.2
1979-80	1700	739	2439	30.3
1980-81	1720	844	2564	32.9
1981-82	1654	983	2637	37.3
1982-83	1576	1054	2630	40.1
1983-84	1763	1092	2855	38.2
1984-85	1747	1116	2863	39.0
1985-86	1721	1260	2981	42.3
1986-87	1799	1363	3162	43.1

Other interesting aspects of this report show that more women, both U.S. and foreign, were granted graduate physics degrees in 1986, and the proportion of new postdoctoral positions (one- or two-year positions) increased dramatically in the United States.

The variety of fields in physics offered by U.S. institutions at the graduate level continues to be very high. Table 17 indicates the number of students enrolled in some of the subfields offered at the graduate level during 1985-86.

Table 17. Number of Graduate Physics Students, by Subfield and Years of Graduate Study Completed, 1985-86. Source: AIP Report (Pub. R-207-19).

		Full-time equivalent years of graduate study									Total graduate students	
		≤ 1 yr	2 yrs	3 yrs	4 yrs	5 yrs	6 yrs	7 yrs	8 yrs	≥9 yrs	N	%
Distribution of students	N	2981	2355	1860	1585	1535	945	450	170	130	12011**	
	%	24.8	19.6	15.5	13.2	12.8	7.9	3.7	1.4	1.1		100%
Astrophysics		161	104	84	55	61	65	15	3	5	553	4.6
Bio/medical physics		107	94	61	51	41	27	9	3	3	396	3.3
Electron, atomic, molecular		182	128	146	135	144	88	72	16	14	925	7.7
Elem. particles		311	298	253	231	229	118	42	33	10	1525	12.7
Geo/atmospheric physics		128	127	82	62	68	35	17	5	4	528	4.4
Mathematical physics		224	162	140	109	103	42	39	3	8	830	6.9
Nuclear physics		201	184	123	136	148	100	35	20	16	963	8.0
Optics		241	181	115	57	64	33	18	10	3	722	6.0
Plasma/fluid physics		92	68	80	87	74	57	28	8	11	505	4.2
Solid state		838	731	650	593	552	338	163	64	51	3980	33.2
General physics		296	97	44	1	2	2	1	2	1	446	3.7
Other subfields		200	181	82	68	49	40	11	3	4	638	5.3

* *The distribution of students in each subfield is based on 6679 respondents to this question.*
** *The total was derived from the survey of Enrollments and Degrees.*

The normal pattern of graduate education in physics for a PhD program consists of two years of course work (including advanced courses in classical mechanics, electromagnetism, quantum mechanics, and mathematics) followed by three or four years of research in an area of concentration. Graduate students normally take a comprehensive exam of course work plus the presentation and defense of an original thesis. The intensive research work is performed either on an experimental or theoretical basis. Table 18 contains interesting data about graduate work in physics.

Table 18. Number* of Advanced Graduate Physics Students Specializing in Selected Experimental or Theoretical Subfields by Years of Graduate Study. Source: AIP Report (Pub. R-207.19).

Physics subfield	Type of research	Full-time equivalent years of graduate study							Total		
		3 yrs.	4 yrs	5 yrs	6 yrs	7 yrs	8 yrs	≥9 yrs	N	% Exp	% Theo
Astrophysics	experimental	49	36	38	30	10	2	5	170	3.8	
	theoretical	40	20	18	32	4	2	1	117		5.3
Bio/medical	experimental	49	38	36	28	8	3	3	165	3.7	
Electron, atomic molecular	experimental	106	112	97	65	57	14	14	465	10.4	
	theoretical	32	24	41	24	14	3	1	139		6.3
Elem. particles	experimental	162	140	110	93	35	22	6	568	12.7	
	theoretical	102	100	122	32	10	12	3	381		17.3
Geophysics	experimental	55	44	48	18	16	5	2	188	4.2	
Math. physics	theoretical	140	110	112	44	38	4	8	456		20.7
Nuclear	experimental	69	91	105	85	22	19	11	402	9.0	
	theoretical	52	52	40	18	14	2	5	183		8.3
Optics	experimental	96	51	65	30	16	7	3	268	6.0	
Plasmas	experimental	53	51	38	32	12	6	5	197	4.4	
	theoretical	31	38	38	26	12	2	5	152		6.9
Solid state	experimental	490	430	407	269	142	51	45	1834	41.0	
	theoretical	163	149	139	60	18	9	4	542		24.6
Other subfields	experimental	76	52	28	32	15	6	6	215	4.8	
	theoretical	95	47	53	27	7	1	3	233		10.6
Total	experimental	1205	1045	972	682	333	135	100	4472	100.0%	
	theoretical	655	540	563	263	117	35	30	2203		100.0%

* *The numbers in this table have been scaled up to reflect the total number of graduate students (6675) who completed three or more years of graduate study.*

There are several sources of support for graduate physics students, including teaching assistantships funded through the institutions of higher education and research assistantships, which could be funded from research grants and/or the corresponding institution. Other sources of support include fellowships from national organizations, government agencies, and industry. Table 19 shows some statistical data on the support offered to graduate students.

Table 19. Sources of Support for Graduate Physics Students, by Sex and Degree Status, 1985-86. Source: AIP Report (Pub. R-207.19).

				Candidates for:				Total	
Source of support		Female	Male	Terminal master's	Master's enroute to PhD	PhD after master's	PhD only	N	%
Teaching assistantship		39%	35%	46%	49%	27%	34%	2417	36
Research assistantship		40	46	20	30	56	51	3076	45
Fellowship		10	8	4	8	8	11	564	8
Foreign government		2	1	1	2	1	1	95	1
Family, savings, loan		3	2	5	3	2	1	149	2
Part-time employment		2	3	7	3	2	1	177	3
Other, including multiple sources of support		4	5	17*	5	4	1	312	5
		100%	100%	100%	100%	100%	100%		
Total respondents	N	892	5898	705	1503	2848	1734	6790	
	%	13	87	10	22	42	26		100%

Includes masters who worked full-time to support their graduate studies.

Table 19 indicates that Master's degree candidates are likely to be offered teaching assistantships, whereas research assistantships are more prevalent among PhD candidates. Foreign students are not always supported by their native countries. These students, according to the AIP data, are mainly supported by U.S. colleges and universities through regular assistantships.

This report on physics education would not be complete without mentioning the situation and contributions of minority groups. These groups have been underrepresented in physics for several years. During teh past 30 years, however, there has been considerable gain in terms of the number of graduates at all levels (Bachelors, Masters, and PhDs). The data for these groups, analyzed by several agencies including the federal government and the American Institute of Physics (AIP), shows some increases in the participation of minorities. The results of recent surveys conducted by the AIP list specific minority groups by sex but irrespective of citizenship (Table 20). The main sources for the survey were: (1) reports from physics department chairpersons and (2) identification with minority groups by individual graduates.

Table 20. Number of Physics Degrees Granted by Sex and Minority Groups* Status, 1985-86. Source: AIP Report (Pub. R-207.19).

Type of degrees	Sex	Total no. of degrees	Black	Native American Indian	Hispanic	Oriental	Asian Indian	Arab
Bachelor's	Men	4494	162	15	50	117	37	37
	Women	720	29	3	8	29	13	1
	Total	5214	191	18	58	146	50	38
Master's enroute	Men	762	6	3	11	146	46	22
	Women	108	7	0	0	29	12	6
	Total	870	13	3	11	175	58	28
Terminal master's	Men	600	23	4	12	59	27	19
	Women	113	2	1	0	14	13	3
	Total	713	25	5	12	73	40	22
Doctorate	Men	958	7	2	27	108	47	24
	Women	93	2	0	0	10	15	7
	Total	1051	9	2	27	118	62	31

**Minorities in AIP surveys are defined as groups with a low representation in the physics community, but ones whose participation has aroused considerable interest.*

Efforts to Improve Physics Education

In the United States there has been a continuous trend to improve physics education, particularly at secondary and tertiary levels, although some periods of little activity can be found.

The period between 1950 through the end of the 60s was marked by rapid growth in the size of the physics departments in the colleges and universities across the nation. Curricular changes, development and implementation of new projects in physics education, publishing of new textbooks with new dimensions, and modified teacher training programs (institutes) for high school and college teachers were some of the innovations introduced during those years.

At the high school level the Physical Science Study Committee (PSSC) produced a modern and new approach to teaching physics. Textbooks, laboratory manuals, new and inexpensive equipment, excellent teachers' guides, and audio-visual materials including excellent films were completed. The PSSC, as it is still known, made a tremendous impact upon the traditional high school physics courses. Funds were available for training high school teachers using the PSSC materials. The interest in this new approach reached many nations. It was a unique combined effort in the United States with strong international repercussions. Moreover, another project followed the PSSC. It was the Harvard Project Physics Course. The amount of material produced by this second project was incredible. The Harvard Project was an effort to reach all the spectrum of high school students from the average to the brightest. Many schools across the nation and abroad still report using the PSSC or the Harvard Project.

At the college or university level major efforts to improve physics education were undertaken during the 50s through the end of the 60s. One of the most successful attempts in physics education was the establishment of the Commission on College Physics in 1959. The Commission did excellent work in analyzing the problems of teaching and learning in physics. It encouraged and prepared reports on new introductory physics courses, produced reports on numerous changes in physics teaching, successfully offered all kinds of conferences on major programs in physics, both for undergraduate and graduate programs, and maintained strong interests in the development of laboratory work as vital to the success of an introductory physics course.

The teaching faculty of the universities during the mid-50s, 60s, and even the beginning of the 70s saw and participated in the development of new course materials, new laboratory experiments, design and construction of laboratory equipment, and physics buildings to house larger numbers to students.

It was during those years that the Feynman Lectures on physics, still one of the best reference books in the market, the Berkeley Course Texts, the Berkeley Physics Laboratory, and the first edition of Physics for Scientists and Engineers by Halliday and Resnick were published.

The new concept of short silent films, known as film-loops, became available. The film-loops are still available in most physics departments across the nation. Other projects such as the Physics Demonstration Experiments by Harry Meiners and courses such as the Dartmouth Course, the Bryn Mawr Course, the Washington University Course, etc. made big strides in physics education.

Summer institutes and workshops were offered for college and high school teachers which were sponsored by the National Science Foundation. Those years were indeed a "Golden Era" for physics education.

During the 70s, however, the level of activity decreased. Several factors influenced the situation in the United States, including among others, the world energy crisis and an economic recession.

The Commission on College Physics ceased to exist legally in August 1971, and the American Association of Physics Teachers (AAPT) assumed complete responsibility of the Commission's role and expanded the activities through the Council on Physics Education. The last newsletter of the Commission on College Physics included an excellent report on the conference "Priorities for Undergraduate Education." The report included "deeper worries" about the future generation of students and professionalization of faculties which was influencing the contents and methods of undergraduate education. The report continued analyzing the situation of the physics faculty in the universities showing a lack of interest in the outside world (industry or governmental experience) and disregard for the average student. The report ended with interesting recommendations for the faculty, administrators, and the government.

The last few years of the 70s were very difficult for the physics community due to a lack of funds for teaching innovation, but the AAPT continued their work with the resources available. The 70s brought concerns among the physics community about environmental issues, physics and society, national defense issues, and energy sources. Courses on energy and power were developed and books and articles on solar energy, renewable and non-renewable energy sources, conservation of energy, physics and society, etc. were published.

Moreover, and in spite of a lack of funds for physics education, the Self-Paced Method of Instruction (Keller's Plan) was adapted to physics instruction. In many physics departments, it was adapted and/or modified to satisfy the needs of the students. Also, with more modern technology available, the production and use of videotapes and synchronized slide tapes as teaching aids were rapidly expanded.

The AAPT and other organizations associated with physics teaching maintained the faith of physics teachers for better times. The decade of the 70s was not very productive for high school physics. No major accomplishments were made except for isolated efforts reported in the Science Teacher and The Physics Teacher.

The 80s offer new challenges for physics teachers at all levels. Aging faculty in the universities, presence of obsolete equipment, needs for better trained high school teachers and improving physics instruction at all levels, together with demographic changes and needed action to improve competitiveness by the nation's industry in the world market, present an extraordinary task for the physics community.

Serious studies and surveys have been undertaken by the National Science Teachers Association (NSTA), the American Institute of Physics (AIP), the American Physical Society (APS), and the American Association of Physics Teachers (AAPT).

Attendance and interest in the Winter and Summer Meetings of the AAPT has increased. Funds for improvement of physics teaching, preparation of high school teachers, acquisition of laboratory equipment, etc. are now readily available through the National Science Foundation. Moreover, donations from industry to universities and workshops and summer institutes for high school and university teachers sponsored by industries and other national organizations are being offered.

The participation of the United States in the International Physics Olympiads is a very positive project undertaken by the AAPT.

The Physics Teaching Resource Agent program (PTRA), started in 1985, is one of the most ambitious and successful projects undertaken by the AAPT. This project, designed for high school teachers, has trained more than 300 teachers to serve as needed resources for teachers at the secondary level.

Other projects at present include Physics in the High Schools, a nationwide survey of secondary school teachers sponsored by the American Institute of Physics. The Introductory University Physics Project, a joint project of AAPT, AIP, and APS, is going forward in its effort to analyze and make recommendations on introductory physics courses. The Annual Conference of Physics Department Chairs, sponsored by the AAPT, is providing the physics community with serious input and analysis of the situation in physics. Commercial workshops and AAPt-sponsored workshops on the use of computers in physics teaching are being offered through the year, particularly during the Winter and Summer AAPT meetings and at local meetings throughout the United States.

A new era of introductory physics textbooks is envisioned through the 90s, and computers are becoming readily available from high schools through the institutions of higher education. The Optical Society of America is sponsoring workshops for high school and college teachers on fiber optics and applications of holography in industry. There are also serious attempts being made by the Council on Undergraduate Research to assess undergraduate research in science taking place in colleges and universities across the nation.

Moreover, the participation of U.S. physicists and teachers in international conferences is seen as an excellent exchange of ideas and the opportunity for U.S. physics teachers to analyze and even experiment with successful teaching approaches used in other nations. The most recent experience was the participation of the United States in the Inter-American Conference of Physics Education held in Oaxtepec, Mexico (1987). This Conference, sponsored by several international organizations including the Organization of American States (OAS), UNESCO, ISPAP, etc. and AAPT, gave U.S. teachers the opportunity to interact with teachers from several countries of the Western Hemisphere, Europe, Asia, etc. on the establishment of networks in physics education.

As a result of the conference in Oaxtepec (Mexico), the AAPT convened six Topical Network Groups (TNG) in Crystal City (Virginia) on January 23, 1988, to discuss ways in which networking activities in physics education in the United States could be strengthened. Sixty U.S. physics teachers took park in the meeting and discussed topics ranging from education and training of high school teachers through physics and technology (See AAPT Announcer 18, No. 2, May 1988).

The American Physical Society, on the other hand, is offering a program known as Physics Local Alliances to assist local school systems in improving high school physics teaching.

On a different dimension, the Physics Division of the American Society for Engineering Education (ASEE) is trying to provide a liaison between physics and engineering educators. Participation of faculty members from the engineering and physics professions in the ASEE-Physics Division has been increasing for years.

The 1990s promise more challenging tasks for physics educators.

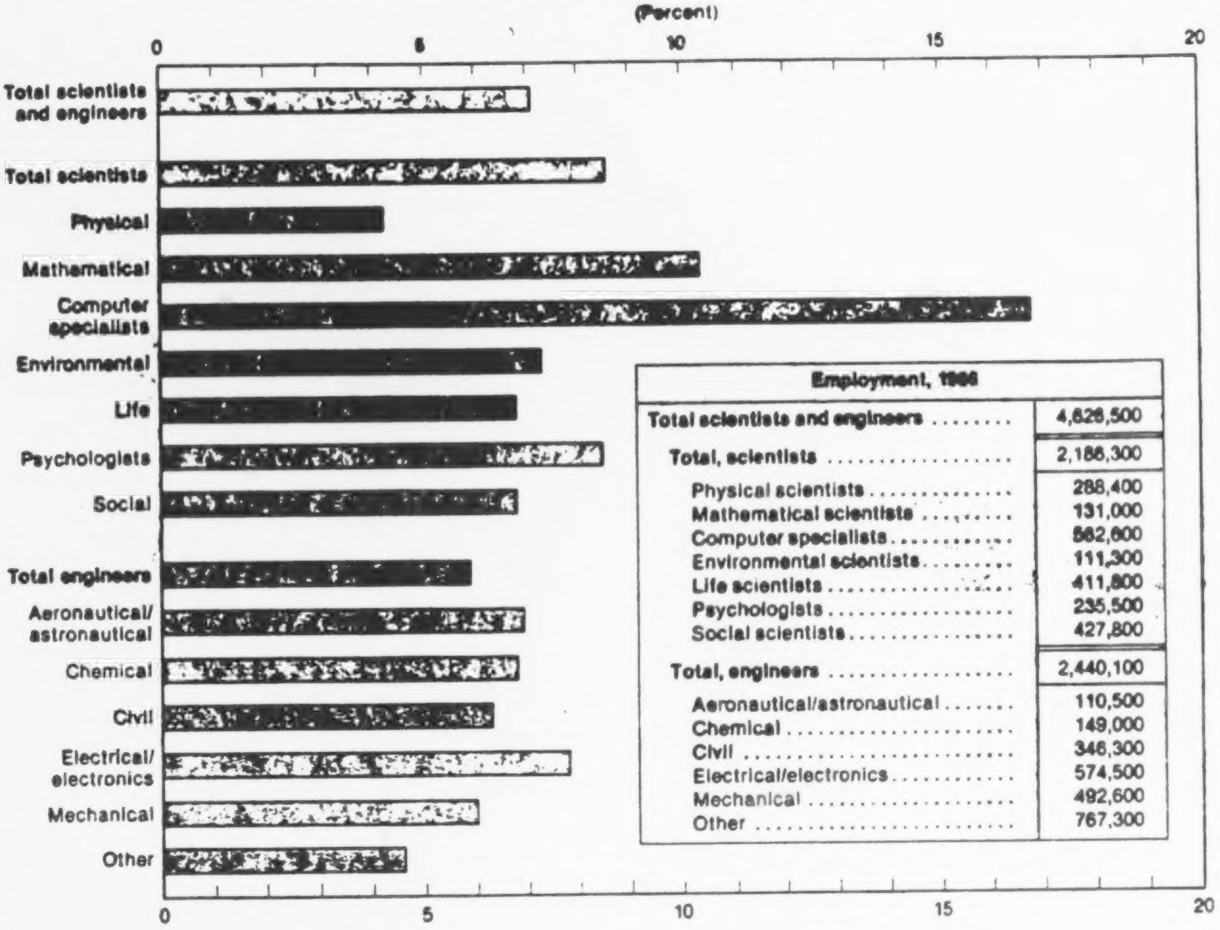
The Professional Physicist

The United States has always relied on its scientists and engineers for economic growth, national security, and international competitiveness. According to the data obtained from the National Science Foundation (Science Resources Publications No. NSF-88-305, 1987), in 1986 there were about 2.4 million engineers and 2.2 million scientists employed in the United States with 85% of the total engaged in science and engineering activities.

The major employer of U.S. scientists and engineers is industry followed by academia, the federal government, and other levels of government (state and local).

Physicists in the United States have been involved for years in a variety of work activities; however, basic research, teaching, and applied research predominate. Their participation in academia, industry, national laboratories, and other research institutions have been very important in the country's development and technological sophistication.

Figure 2 shows the average annual rate of employment growth for scientists and engineers during 1976-86.



Employment, 1986	
Total scientists and engineers	4,626,500
Total, scientists	2,186,300
Physical scientists	288,400
Mathematical scientists	131,000
Computer specialists	562,600
Environmental scientists	111,300
Life scientists	411,800
Psychologists	235,500
Social scientists	427,800
Total, engineers	2,440,100
Aeronautical/astronautical	110,500
Chemical	149,000
Civil	346,300
Electrical/electronics	574,500
Mechanical	492,600
Other	767,300

[a] Includes all employed scientists and engineers, 15 percent of whom are employed outside of science and engineering

SOURCE: National Science Foundation, SRS, table B-39

Fig. 2. Average annual rate of science/engineering employment growth, 1976-86. Source: NSF Special Report (NSF 88-302, 1988).

Physicists were mainly employed by academic institutions until 1979 when a rapid decline in teaching as a work activity was observed between 1979 and 1981. After that period, academic institutions again made some recoveries. At present, with better salaries and opportunities, academia is again becoming an attractive profession. The number of physicists employed by industry continues to increase, however, and together with academia constitutes the main source of employment. Full-time employment in academia for individuals with a Master's or Bachelor's degree is often limited because basic research and teaching are the primary concerns of universities and colleges. Thus, these institutions are the domain of doctorates. This is also true for employment at national laboratories, where the prospect of doing basic research is very attractive to the PhD recipient.

Table 21 shows the results of an AIP survey on job offers for doctoral graduates during 1985-86. The distribution by subfiels and employment offers for doctorate recipients for 1985-86 is shown in Table 22. The demands for terminal master's degree recipients is shown in Table 23.

Table 21. Employment of Doctoral Graduates by Citizenship, 1985-86. Source: AIP Report (Pub. R-207.19).

Doctoral graduates		U S employer			Foreign employer		Uncommitted	Total	
		Postdoc	Accepted	Cont	Postdoc	Accepted		N	%
U S citizens		198	151	21	21	1	11	403	66
Foreign citizens		143	22	1	17	25	4	212	34
Total	N	341	173	22	38	26	15	615	
	%	56	28	4	6	4	2		100%

Note Seven doctoral graduates had no immediate plans and one graduate reported 'other graduate study

Table 22. Distribution by Subfields and Employment Offers, 1985-86. Source: AIP Report (Pub. R-207.19).

Physics subfield		Total in subfield	Employment-oriented graduates	New 'postdocs'	Percentage of graduates within subfield who received:		
					0 offers	1 offer	>2 offers
Astrophysics		4.6%	2.0%	2.6%	-	31%	69%
Electron, atomic molecular		11.7	4.6	7.1	3%	54	43
Elementary particles		14.2	3.4	10.8	-	51	49
Geo/Geophysics		3.3	1.2	2.1	-	58	42
Math. physics		5.2	1.6	3.6	7	48	45
Nuclear		10.1	4.1	6.0	2	46	52
Optics		3.4	2.1	1.3	-	60	40
Plasmas, fluids		5.0	2.5	2.5	-	50	50
Solid state		37.5	13.9	23.6	1	51	48
All other subfields		5.0	3.0	2.0	-	43	57
Total	%	100.0%	38.4%	61.6%	1%	50%	49%
	N	1038*	399	639			
All experimental subfields			286	392	2%	50%	48%
All theoretical subfields			113	247	1%	49%	50%

** This total does not include an estimated 13 graduates who were not interested in immediate employment, (see Figure IV). It is the survey of Enrollments and Degrees which supplied this total.*

Note: The "job offer" portion of this table does not include graduates with commitments to foreign employers.

Table 23. Distribution by Subfield and Employment Offers for Terminal Masters, 1985-86. Source: AIP Report (Pub. R-207.19).

Physics subfield	Total in subfield*	Percentage of graduates within subfield who received		
		0 offers	1 offer	2 offers
Acoustics	6.1%	18%	82%	-
Bio/medical physics	4.3	-	67	33%
Engr/applied physics	13.7	9	73	18
Geo/space physics	13.7	6	83	11
Nuclear	5.8	8	75	17
Optics, lasers	11.2	-	74	26
Solid state	21.3	27	58	15
General physics	7.2	-	80	20
All other subfields	16.7	7	80	13
Total	100.0%	12%	73%	15%
Employment-oriented respondents	224	27	163	34

** Based on 277 respondents.*

Table 24 identifies six types of major initial work activities for Master's in Physics. Industry remains the largest single employer.

Table 24. Employment Characteristics of 1985-86 Recipients of Physics Master's Degrees. Source: AIP Report (Pub. R-207.19).

		Type of employer						Total	
Work activity		University	4-yr college	Industry	Government	Military service	Nonprofit organization	N	%
Teaching		13	8	-	-	1	-	22	12
Research		3	1	6	2	1	1	14	7
Res and dev		-	-	23	6	31	3	63	33
Engineering		2	-	36	6	29	-	73	39
Comp science		1	-	4	-	-	-	5	3
Nonphysics		-	-	10	-	-	2	12	6
Total	N	19	9	79	14	62	6	189	
	%	10	5	42	7	33	3		100%

Table 25 shows how the initial employment of Physics Bachelors has changed during the period 1977-1987. It is interesting to notice the substantial increase in the percentage of Bachelor's degree recipients who entered the military service each year. Specialized training, such as pilot training or enrolling in a nuclear power school, has been mentioned as very attractive for the graduates.

Table 25. Initial Employment of Physics Bachelors, 1977-87. Source: AIP Report (Pub. R-211.19).

		Percentage of employed bachelors									
Type of employer		1977-78	1978-79	1979-80	1980-81	1981-82	1982-83	1983-84	1984-85	1985-86	1986-87
Industry	manufacture	37%	40%	41%	40%	38%	33%	38%	35%	30%	28%
	service	21	18	20	22	22	20	16	20	18	18
High school		7	6	3	2	3	4	4	4	7	6
College or university		3	4	3	4	4	4	5	3	4	4
Government	civilian	7	7	8	7	7	10	12	14	13	11
	military	14	15	16	21	24	27	24	23	28	32
Other		11	10	9	4	2	2	1	1	-	1
Total		100%	100%	100%	100%	100%	100%	100%	100%	100%	100%

Table 26 (see next page) shows some interesting data compiled by the American Institute of Physics (Manpower Statistics Division). The employment sector distribution is indicated in Table 27.

Table 26. Research Subfields for Physicists within Selected Employment Sectors, 1983. Source: AIP Report (Society Membership Profile: The Pattern of Subfield Associations by R. Czujko, W.K. Skelton, Beverly F. Porter, and R. Cox).

	University %	Industry %	Government %	Nat'l Labs %
Solid State Physics	17	24	18	14
Plasma Physics	8	9	7	19
Elementary Particles	15	-	2	13
Nuclear Physics	12	4	6	13
Optics	5	16	11	6
Atomic and Molecular	8	4	8	9
Astrophysics	8	1	7	4
Medical Physics	5	5	4	-
Chemical Physics	4	4	4	4
Mathematical Physics	4	3	5	2
Geophysics	2	6	8	3
Materials Science	1	7	4	4
Electronics	1	6	4	1
Biophysics	3	1	1	1
Acoustics	2	3	4	1
Low Temperature Physics	3	2	2	2
Electromagnetism	1	3	3	2
Fluid Dynamics	1	2	2	2

Table 27. Employment Sector Distribution Within Selected Physics Research Subfields, 1983. Source: AIP Report (Society Membership Report, 1983).

	Employment Sector			
	University %	Industry %	Nat'l Labs %	Gov't %
Solid State Physics	42	32	12	11
Plasma Physics	36	22	30	9
Elementary Particle Physics	71	1	20	2
Nuclear Physics	58	10	21	8
Optics	24	44	11	15
Atomic & Molecular Physics	50	11	17	13
Astrophysics/Astronomy	56	4	10	15
Medical/Radiological Physics[1]	39	22	2	8
Chemical Physics/Chemistry	44	26	13	11
Mathematical Physics/Mathematics	44	17	9	16
Geophysics/Earth Science	23	35	10	24
Materials Science	20	46	18	13
Average for 18 Research Fields	42	23	15	11

[1] In medical physics, 27% of the work is in the hospital and non-profit sectors

The corporations employing the largest number of physicists as of 1983 were: AT&T Bell Laboratories, IBM, General Electric, Hughes Aircraft, TRW, Rockwell International, Honeywell, Westinghouse, Exxon, Xerox, Lockheed, Hewlett Packard, Perkin-Elmer, GTE, and Texas Instruments (Source: AIP Report).

The type of employer and principal type of work by employer are shown in Tables 28 and 29 provided by the AIP (Manpower Statistics Division) as a result of national surveys.

Table 28. Type of Employer by Professional Self-Identification, 1983.

	Physicists %	Astronomers %	Engineers %	Chemists %	Computer Scientists %	Other Scientists %	Other %	Total %
ACADEMIC	49	61	21	52	34	52	52	45
University	38	56	19	47	26	43	13	35
Other Academic	11	5	2	5	8	9	39	10
NONACADEMIC	51	39	79	48	66	48	48	55
Industry/Self-Employed	25	11	65	28	52	26	36	32
Government	11	13	7	8	4	10	5	10
FFR&DC	11	9	4	10	3	5	1	9
Nonprofit	4	5	2	2	7	7	5	4
Other	-	1	1	-	-	-	1	-
Total Number Known	3269	247	944	530	67	374	266	5699
No Response	33	4	6	11	0	4	4	63

Table 29. Principal Work Activity by Type of Employer, 1983.

	University %	Other Academic %	Industry %	Government %	FFR&DC %	Other %
Teaching	38	91	-	1	-	3
Basic Research	45	1	10	28	38	21
Applied Research	8	-	30	29	36	20
Development	1	-	18	8	6	5
Design/Engineering	1	-	17	4	5	5
Administration	5	7	16	22	13	13
Consulting/Other	2	1	9	8	2	33
Total Number Known	2003	545	1837	562	489	230
No Response	23	4	9	2	6	3

The research conducted by PhD physicists in the United States is richly diversified. Solid state physics, however, is the largest subfield of physics employment followed by plasma physics, elementary particle, and nuclear physics. Applied areas of high growth are optics and medical physics.

It should be noted that PhD physicists do not necessarily remain in the subfields in which they were trained. It is estimated that only about one half are still working in their degree subfield. Some physicists even move to other areas of science, engineering, and administration. Thus, there is a substantial mobility between the different subfields of physics themselves.

The main organization for physicists in the United States is the American Physical Society (APS), which consists of 12 divisions. Most members belong to one or more of them. These divisions are Astrophysics, Atomic, Molecular and Optical Physics, Biological Physics, Chemical Physics, Condensed Matter, Fluid Dynamics, High Polymer Physics, History of Physics, Nuclear Physics, Particles and Fields, Plasma Physics, and the Forum on Physics and Society.

The APS publishes the internationally known journal Physical Review which, in reality, is comprised of several journals according to the field or topic in physics. It also publishes Physical Review Letters, Reviews of Modern Physics, Bulletin of the American Physical Society, and Physical Review Abstracts. Other journals in physics are published through the American Institute of Physics.

The APS had about 32,694 members in 1985 with about ten percent of them honored with the designation of Fellow. The most APS members outside the United States were in Canada and Japan.

The main professional organization with emphasis in physics education at all levels is the American Association of Physics Teachers (AAPT). This national organization has 40 regional sections, some of which are in Canada. Most of the members teach in institutions of higher education but a substantial number, about 2000, including many officers, are high school teachers. The AAPT has about 10,000 members with approximately 15% of them having addresses outside the United States. Canada and Australia have the most members among foreign countries.

The AAPT publishes the American Journal of Physics, The Physics Teacher, and the AAPT Announcer. The APS and AAPT also publish monographs and other specialized books and conference proceedings.

The APS and AAPT, with other professional organizations such as the Optical Society of America, the Acoustical Society of America, etc., are member societies of the American Institute of Physics (AIP). The AIP has been serving physics, astronomy, and allied sciences since 1931. The AIP is governed by its member societies and publishes several journals for the APS including Physics Today, Journal of Applied Physics, The Physics of Fluids, and Review of Scientific Instruments, to mention a few. The AIP also publsihes translations to English of other journals from the Soviet Union and distributes journals from the United Kingdom, etc. It also runs a Career Placement Division for members who are searching for new jobs in physics.

The activities of the AIP have been of great help to the member societies and the physics community in general. Their publications and programs have served well scientists from all over the world.

To close this section on the professional physicist, it should be noted that industry in the United States has become an increasingly important option for PhDs, Master's and Bachelor's degree recipients.

VENEZUELA

General Information about the Country

Venezuela, situated in northern South America, has a surface area of 912,050 km^2 or 352,143 square miles. It is bordered on the north by the Caribbean Sea (with a coastline of 2816 km). On the south, Venezuela is bordered by Brazil, on the west and southwest by Colombia, and on the east by Guyana. The islands of Margarita, Tortuga, and some smaller islands on the Caribbean Sea are also part of this country.

Venezuela is a republic, consisting of 20 states, 2 federal territories, and the federal district of which Caracas, the capital, is a part. Geographically, the country is divided in four major regions: the Venezuelan highlands (heavily populated), the coastal lowlands, the basin of the Orinoco River, and the Guiana highlands which occupy more than half of the national territory.

Venezuela's income derives fundamentally from oil production, and more than 95% of its foreign exchange and over two thirds of the total income originates from oil exports. Other exports include iron ore, coffee, cocoa, rice, and cotton. The country has an excellent highway system and the income per capita is the highest among the Latin American countries.

Oil revenues have been used, among other things, to stimulate manufacturing industries such as food processing, textiles, shoes, chemicals, and automobiles.

The population of Venezuela is estimated at about sixteen million. The ethnic composition (1981) was 69% mestizo, 20% white, 8 to 9% Black, and the rest native Indians. During the 70s the population growth was among the highest in the world.

The percentage of the national budget dedicated to education is approximately 17.7%. According to the figures obtained for 1985, illiteracy in Venezuela was not very high. The data indicates that 88.4% of the population was literate (figures might be higher now) with 90.3 of the male population and 86.3 of the female population being literate.

The Educational System in Venezuela

The pre-college component of the educational system in Venezuela is highly centralized, as it is in most South American countries. Decisions on curriculum, teacher qualifications, and standards for elementary and secondary education are determined by the National Ministry of Education. Therefore, the curriculum at all pre-college levels is uniform across the nation.

The educational system of Venezuela was re-organized in 1983, and in the new organization it is divided as follows:

A) First Level or Basic Education

This basic cycle is subdivided in three stages. The first stage comprises grades 1 through 4, the second stage includes grades 5 through 7, and the last stage consists of grades 8 and 9.

Children start their formal education at age four in pre-school and progress through the system according to their age. The first level or basic education is attended by children 7-15 years old. It should be noted that this level includes primary and part of the secondary education.

B) Diversified Cycle

This level lasts two or three years, depending on the option selected by the student. The graduates from this cycle are able to go on to higher education or to enter the work force as qualified middle technicians.

In this level there are several options or categories, namely:

1) Secondary (Science and Humanities)
2) Agriculture
3) Industrial
4) Business and Commerce
5) Health and Paramedical
6) Elementary School Teaching.

The option called secondary is for college-bound students (college preparation) and does not qualify them for any particular job. The other options give the students some skills (vocational), except for the elementary school teaching option that was used for the preparation of primary school teachers. This category is being phased out because the 1980 Law on Education states that school teachers should have a university degree.

C) Third Level of Education

The third level of education offers several alternatives and comprises three types of institutions of higher education: universities, institutes, and colleges. The universities offer traditional undergraduate programs with a duration of five to six years and some four-year degrees in certain fields. Physics is taught in the universities at all levels--introductory, intermediate, and advanced--with undergraduate- and graduate-level degrees awarded.

The institutes are of two types: pedagogic institutes where the secondary school teachers are prepared (four years), and polytechnic institutes where five-year degrees in different fields of engineering are offered. These degrees in engineering are similar to those offered in the universities. Introductory- and intermediate-level courses are taught in these institutions.

The colleges offer two- to three-year programs leading to a high-level technical degree in areas such as engineering technology, business, special education, social and health sciences, and so forth. Physics education in these colleges deals with teaching introductory physics to students in different branches of engineering technology.

There are other types of institutions that in principle are similar to the British open universities: open university, open studies. They are able to grant some university degrees (typically four years). The curriculum in the open studies includes physics courses at introductory and intermediate level. Open studies may confer a high school teaching degree in physics or mathematics.

According to the statistics (1982) of the University Sector Planning Office, 331,115 students were enrolled in about 70 institutions of higher education.

Figure 1 shows the different levels of education according to the re-organization of the educational system (1983). This system has not been fully developed and part of the old organization shown in Fig. 2 is still in operation. The main difference between the "old" and "new" organization is in the first level of instruction which now lasts nine years instead of six, because the three years of the common basic cycle of the old system are now included in the first level or basic education.

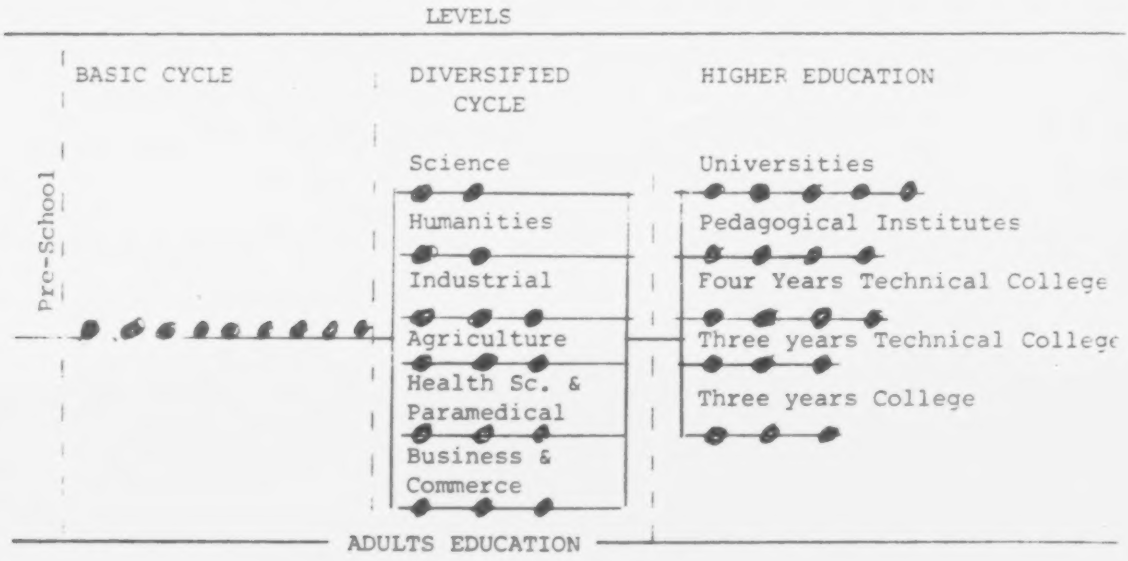

LEVELS
BASIC CYCLE
DIVERSIFIED CYCLE
HIGHER EDUCATION
Pre-School
Science
Humanities
Industrial
Agriculture
Health Sc. & Paramedical
Business & Commerce
Universities
Pedagogical Institutes
Four Years Technical College
Three years Technical College
Three years College
ADULTS EDUCATION

Fig. 1. The new educational organization in Venezuela.

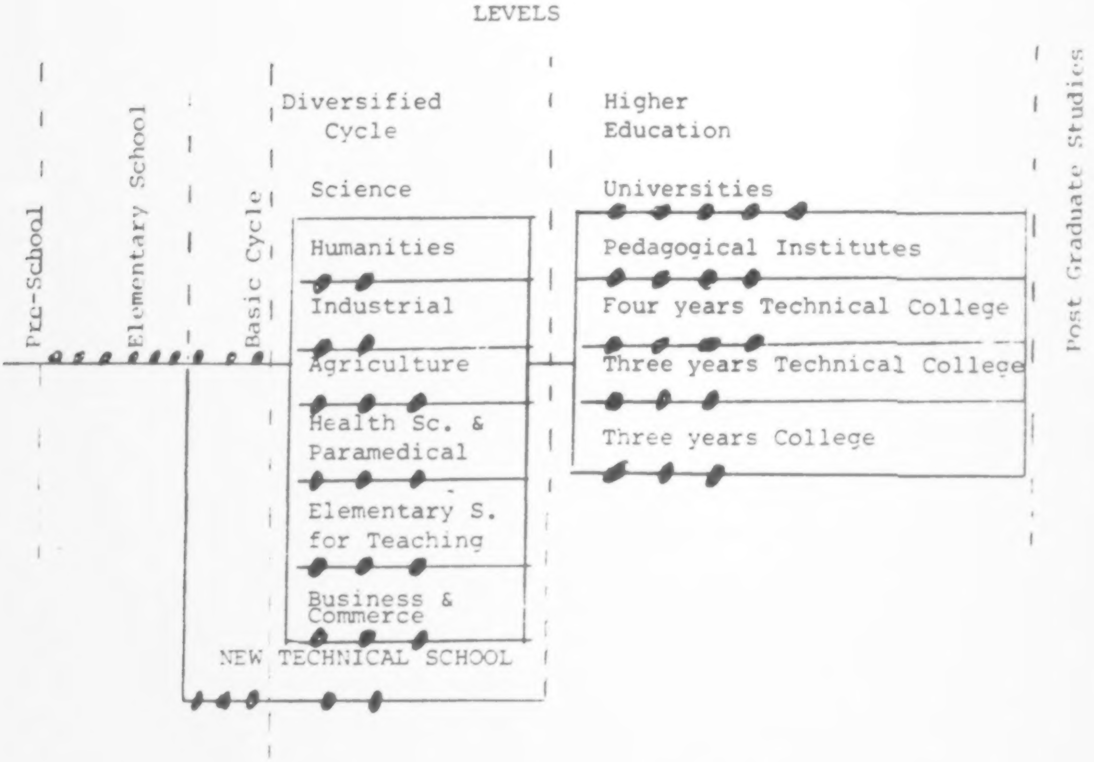
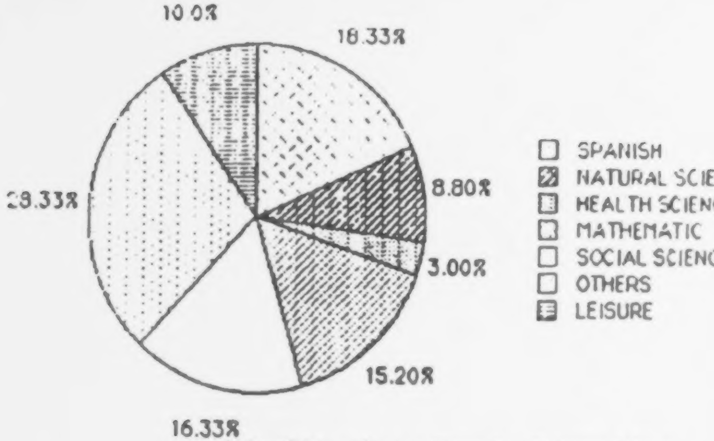

LEVELS
Pre-School
Elementary School
Basic Cycle
Diversified Cycle
Science
Humanities
Industrial
Agriculture
Health Sc. & Paramedical
Elementary S. for Teaching
Business & Commerce
NEW TECHNICAL SCHOOL
Higher Education
Universities
Pedagogical Institutes
Four years Technical College
Three years Technical College
Three years College
Post Graduate Studies

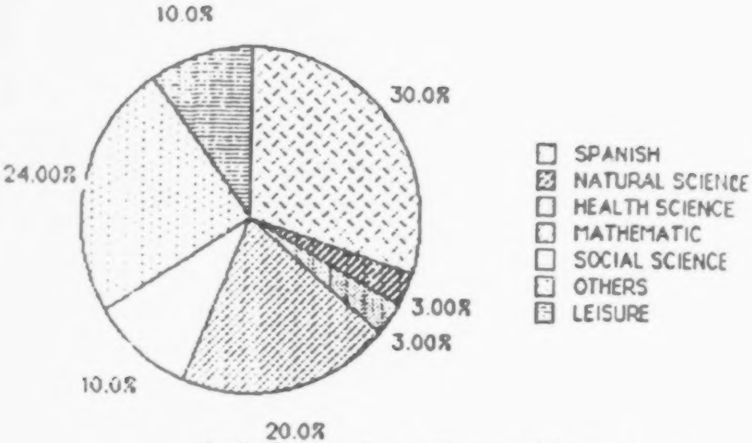
Fig. 2. The education system in Venezuela before the re-organization (1983).

Physics Education in the Basic Education Level and in the Middle and Diversified Cycles

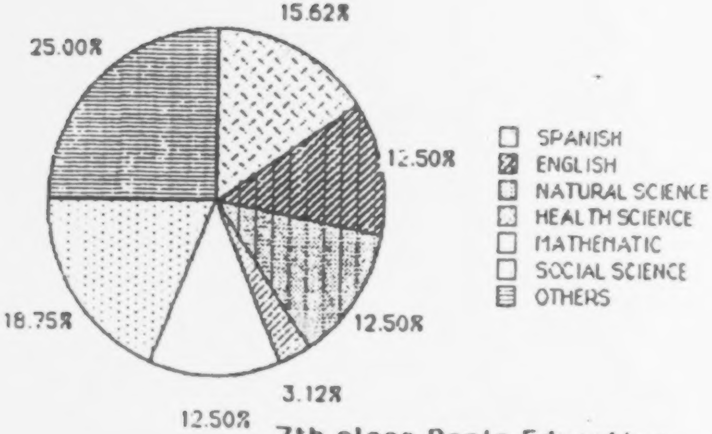
Physics topics have been inforporated in the natural science component of the basic education level from grades 1 through 7. The physics concepts are aimed at acquisition of the basic scientific knowledge for interpretation of natural phenomena, providing a frame of reference for preservation and conservation of the natural environment. The topics are focused on the development of reasoning skills and creativity and cover a broad spectrum of themes selected from mechanics, optics, and electromagnetism.



4th-6th class Basic Education



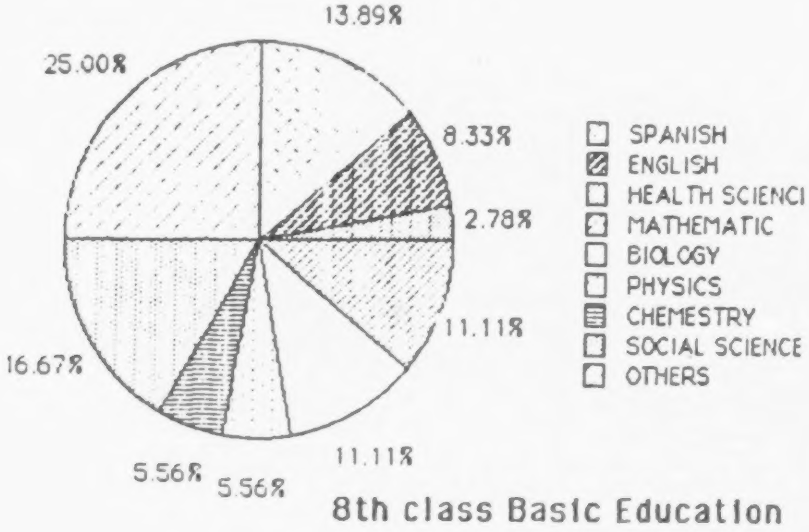
1st-3rd class Basic Education



7th class Basic Education

Fig 3. Percentages dedicated to the different disciplines in grades 1-7.

During the 8th and 9th grades science is separated into physics, chemistry, and biology. These curricula are still in the process of implementation. Figure 4 (below) shows the situation for grades 8 and 9 of the basic education level.



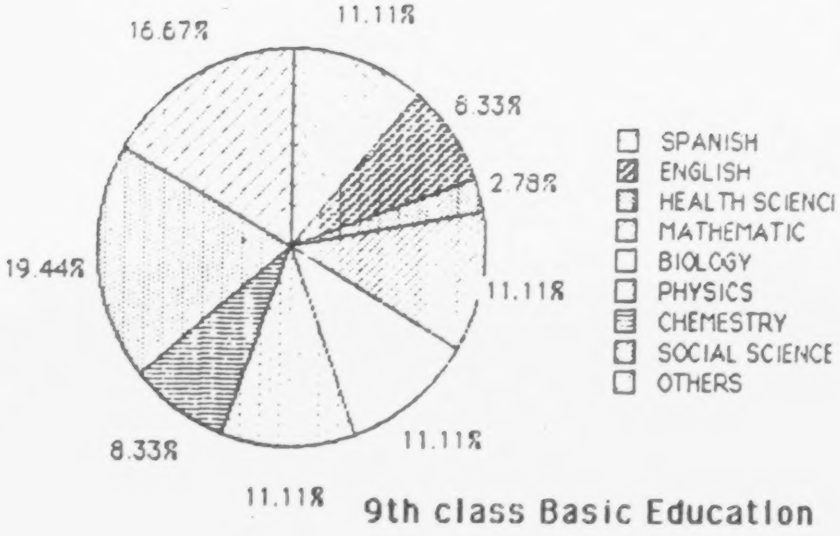


Fig. 4. Percentages dedicated to the different disciplines in grades 8 and 9.

Table 1 shows the different subjects, physics included, in the curriculum of the basic education level. The average amount of time dedicated to each subject is also indicated.

Table 1. Basic Education Level.

Subjects	Years 1-3 Minutes/Week	Years 4 - 6 Minutes/Week	7th Year Hours/Week	8th Year Hours/Week	9th Year Hours/Week
Spanish	450	275	5	5	4
English	-	-	4	3	3
Natural Science	45	132	4	-	-
Health	45	45	1	1	1
Mathematics	300	228	4	4	4
Biology	-	-	-	4	4
Physics	-	-	-	2	4
Chemistry	-	-	-	2	3
Social Science	150	245	6	6	7
Others	360	425	8	9	6
Leisure time	150	150	-	-	-

During the diversified cycle, the contents and teaching of biology, chemistry, physics, and physical science reflect the conceptual and procedural structure that characterize these subjects. However, there have been some refinements in the science curricula due to the diversification of the technical, agricultural, and vocational options. Thus, there are courses offered in botany, zoology, soil science, microbiology, and others. Also, in the technological areas there are special courses in electronics, mechanics, small engines, etc. See Tables 2 and 3 for more data on the diversified cycle.

Table 2. Number of Students Registered in the Diversified Cycle, First Year.
Source: Report and Statement of the Ministry of Education, 1985.

		COLLEGE BOUND DIVERSIFIED		TECHNICAL & COLLEGE BOUND DIVERSIFIED			
#/%	Total	Science	Humanities	Industrial	Agricultural	Health&Science Paramedical	Business &Commerce
#	143,332	96,540	19,518	8,461	2,931	3,713	12,169
%	100	67.35	13.62	5.90	2.05	2.59	8.49

Table 3. Current Plan Diversified Education (1983).

AREAS	Secondary Cycle n = 2 years				Technical Cycle n = 3 years					
	Science		Humanities		Industrial		Agriculture		Health Service & Paramedical	
	average Hs/week	%	average Hs/week	%	average Hs/week	%	average Hs/week	%	average Hs/week	%
General Study (commom for all) i.e.: Literature, Venezuelan History, English, Physics Education.	10	33	11.5	38.3	6	16.5	6.33	16.72	6.66	18.33
Sciences i.e.: Physics, Chemistry, Biological Science, Earth Science.	13.5	45.3	-	-	4.43	12.19	9.11	24.06	2.66	7.32
Mathematics	4	13.3	3.5	11.6	3.33	9.16	2.33	6.15	2.66	7.32
Technological Subject & Technical Training	-	-	-	-	18.9	52.03	17.05	45.05	19.22	52.90
Others: i.e.: Social Science, Philosophy, Psychology, Sociology.	2.5	8.33	15	50	3.66	10.0	3.05	8.05	5.11	14.06
Average Hour/Week	30	100	30	100	36.32	100	37.85	100	36.33	100

Preparation of Primary and Secondary School Teachers

The quality and quantity of teachers during the past 20 years have been dominated by the explosive demand for education from all sectors of the population. Consequently, the main emphasis has necessarily been on the quantitative aspects of the problem.

Until recently the preparation of elementary school teachers was not carried out at the third institutional level (universities and institutes) but only at the diversified cycle of the secondary level (primary school teaching option). Therefore, the adequacy of a three-year training course at the secondary level in order to be an elementary science teacher has left much to be desired. The time devoted to science education during their preparation was about 15%.

The problems associated with the preparation of teachers for the second level of education (basic plus diversified cycle) are more diverse, since two types of teachers are needed: those for each of the sciences and those for technical subjects. In spite of the fact that eight higher education institutions (pedagogical institutes and universities) are devoted to pre-service science teacher training in each separate discipline and four devoted to training teachers in technical subjects, the shortage is quite critical, especially in the latter.

In the integrated science curriculum of the basic education level the lack of trained teachers is almost absolute. Measures are now being taken to train this type of teacher. Although a reform of the pedagogical institutes is in progress, only two are already offering experimental curricula.

The percentages dedicated to science instruction, field experience, and educational science varies from one institution to another. Table 4 shows the mathematics and physics components of a typical curriculum offered by the Pedagogic Institute of Caracas. The requirements for this degree are 59 credit units in physics, 21 in mathematics.

Table 4. Pedagogic Institute of Caracas: Preparation of Secondary School Teachers (Required Credits in Education Not Listed).

	Credit Units		Credit Units
General Physics, I	4	General Physics II	4
Int. Algebra	4	Linear Algebra	4
Calculus I	4	Calculus II	4
Analytic. Geometry	3	Int. Statistics	2
Vectorial Calculus	4	Differential Equations	4
Mechanics I	4	Elect. & Magnetism	4
Physics Lab. I	2	Physics Lab. II	2
(El. 1) Learn. Th. of Phys.	3	(El. 2) Phys. Teach. Seminar	2
Waves and Optics	4	(El. 4) Mech. II	4
Phys. Lab III	2	(El. 5) Stat. Phys.	4
Quantum Physics	4	(El. 6) Phys. Curr. for High School	3
(El. 3) Hist. Ideas of Phys.	3	(El. 7) Design of Expts. High School	2

(Electives also include: Quantum Mech., Math., Phys., Intro. to Programming, Phys. Lab IV, V, Intro. to Electromagnetic Theory).

In addition to the subject matter requirements, students must have approved 17 credits of general education plus 23 in the area of professional pedagogy. Thus, the total number of credits required is 120. The student is expected to graduate in five years. Table 5 shows these requirements.

Table 5. Pedagogic Institute of Caracas: Physics Teachers Program Education Requirements.

General Formation	Professional Pedagogy
Int. Philosophy	Philosophy of Education
Gral. Psychology	Psychology in Education
Gral. Sociology	Sociology of Education
Lang. & Communication	School Administration
Foreign Language	Evaluation I
	Didactics of Physics
Total credit units: 17	Total credit units: 23

One important observation in connection with the curriculum of the Pedagogic Institute of Caracas is that the student has, in principle, ample opportunity to choose among different sequences to meet his/her degree requirements (a major in physics with a minor in mathematics, and vice versa, are possible and common). It is estimated that currently there are about 230 students of teaching physics or physics and mathematics in the country, following a syllabus similar to that shown in Tables 4 and 5. There are problems here, however. Of the 197 students registered in the Math and Physics Department at the Pedagogic Institute of Caracas, only two are being prepared according to the curriculum shown in Tables 4 and 5.

Physics Education at the Third Level (Universities and Pedagogical Institutes)

A) Introductory Physics Courses

A typical introductory physics course at any one of this type of institution includes lectures and laboratory sessions over the first four terms, i.e., one and a half to two years, with five credit units for lecture courses and two credit units for laboratory sessions. Lectures usually include two hours per week or problem-solving sessions, and problem handouts.

Course content varies according to the main career pursued by the individual student. It usually includes: kinematics, Newton's laws, mechanics of the rigid body, laws of thermodynamics, kinetic theory, electricity and magnetism (integral form of Maxwell's equations), harmonic oscillator, gravitation, and some geometrical optics. Physics and electrical and electronic engineering majors are required to study, in addition: waves, E-M waves, interference and diffraction, and old quantum physics.

The most popular textbooks are: Halliday and Resnick, Tipler, Alonso and Finn, plus a few selected chapters from the *Berkeley Physics Course*, *Feynman Lectures*, and French's *Newtonian Physics and Waves*.

B) Undergraduate Degree in Physics

According to the university tradition in Venezuela, undergraduate degrees in the sciences and engineering last about ten semesters (a semester is comprised of about 17 weeks of work). In some universities, such as the Universidad Simón Bolívar, every year consists of three terms plus a summer term. Each of these terms lasts about 12 weeks, very much like some U.S. institutions, yet the undergraduate curriculum in physics requires five years.

Table 6 shows the curriculum for an undergraduate degree in physics in the oldest and largest university in Venezuela, the Universidad Central de Caracas.

Table 6. Universidad Central de Venezuela: Physics Majors Program.

1st Year	Credit Units	2nd Year	Credit Units
Math I, II	12	Math, III, IV	12
General Physics, I, II	10	Mechanics	6
Chemistry I, II	8	Electricity & Magnetism	6
Chemistry Laboratory	2	Physics Lab. I, II	10
3rd Year		4th Year	
Math. Methods I	6	Math Methods I	6
Waves and Optics	6	Quantum Phys. II	5
Quantum Physics I	6	Phys. Lab III	5
Electronics	6	Electromagnetism	6
Phys. Lab III	5	Class. Mechanics	5
Statistical Physics	6		
5th Year			
Quantum Mechanics	6		
Solid State Physics	5		
Project Work (Research Oriented)			

In this program, the student should be enrolled in about 35 credit units per year. Upon completion of the general physics courses, the student has practically covered three of the volumes of the Berkeley Physics Course (underlined in the table). Students enrolled in this program are also required to complete 9 credit units in foreign languages and humanities and 15 units of tutoring. The total number of credit units in this physics program is 167.

The other example of an undergraduate degree program in physics is the one now in effect at the Universidad Simón Bolívar, located just outside the city of Caracas, which is based on 222 credit units (quarter units). Table 7 shows the required course work.

Table 7. Universidad Simón Bolívar: Physics Majors Program.

1st year	Credit Units	2nd Year	Credit Units
Math I, II, III	14	Math IV, V, VI	12
English	9	Algebra	12
Man & Environment, *or*, Soc. Science	8	Physics III, IV	8
Physics I, II	8	Waves & Optics	4
Practicing Spanish	9	Phys. Lab	6
		Programming	3
3rd Year		4th Year	
Math VII	4	Math. Methods	4
Class. Mech I, II	6	Electromagnetism III	3
Phys. Lab IV, V, VI	12	Statistical Phys. I, II	6
General Studies	9	General Studies	6
		Electives	9
5th Year			
Int. Quantum Mech.	3		
Advances Phys. Lab	8		
Electives, *or* Project Work	9		

It should be mentioned that at the Universidad Simón Bolívar, students have two alternatives to complete their undergraduate degree:

i) completion of a research project
ii) completion of three elective advanced courses.

A student who intends to pursue graduate work MSc or PhD) is asked to take the research option, otherwise he/she will not be admitted for graduate work.

The level of the undergraduate courses in physics could be understood by a brief list of the textbooks in use. The *Berkeley Physics Course* (Vol. 1, 2, 3, 4) and Eisberg and Resnick's *Quantum Physics* dominate the intermediate level. Classical Mecianics is taught first using books such as those by Marion, Landau, or Symon, followed by Goldstein's famous text. In Electromagnetism, the books by Corson and Lorraine, the one by Wangness, or Marion and Heald are very popular. The definitive choice for the advanced course in electromagnetism is *Classical Electrodynamics* by J.D. Jackson (at least the first seven or eight chapters are usually covered). Reif's *Statistical and Thermal Physics* is also a common requirement. *Quantum Mechanics* is taught using the French book by Cohen-Tannoudji, Diu, and Laloe. The first four chapters are covered at undergraduate level with the remainder of the textbook covered among the elective courses.

The courses in mathematics in the undergraduate curriculum include calculus, transformations, differential equation, complex analysis, and linear algebra. The textbooks used include *Linear Analysis* by Kreyder et *al*., and Boyce and DiPrima's *Differential Equations*. Finally, mathematical methods are usually taught using Arfken's textbook.

The undergraduate studies in physics at the Universidad Central de Caracas and Universidad Simón Bolívar are said to be research oriented, but there are certain basic differences between them. For instance in the latter there are more units in general education (literature, history, social sciences, and others). Also, the students are free to choose 15 units (quarter units) of electives in physics with the approval of the faculty. The electives include courses on field theory, solid state, plasma physics, mathematical-physics, etc. The curriculum in the Universidad Central is less flexible and certainly less costly for the institution.

There are some attempts in these curricula to offer some career options to the students, allowing them to do their research projects in metallurgy, biophysics , and even in physics education. The Universidad Simón Bolívar is offering a well-articulated undergraduate curriculum in geophysics.

While the curriculum in both institutions lasts about five years, the data obtained indicate that it takes six to seven years for the students to complete the undergraduate degree in physics. The average time spent by the student during 1971-76 was 6.23 years.

The requirements for an undergraduate degree in physics in Venezuela are higher than in most universities around the world. Most graduates can go directly into PhD programs in Venezuela or abroad because of their strong background in physics.

A final figure regarding the popularity for a physics career in Venezuela shows that of the 331,115 undergraduate students (1981-82 academic year), only 1,122 were physics majors (0.336% of the total). The actual figure was even lower since many of these students changed later to engineering programs. In 1986 it was estimated that there were 514 physics majors in the country (freshman-sophomore).

Efforts to Improve Physics Education in Venezuela

The efforts to improve physics education in Venezuela will be divided into roughly three chronological steps: up to 1960, from 1960 to 1980, and from 1980 to date.

Before 1960 the science curriculum was organized as a textbook index, mostly in historical sequence. Although experimental work was prescribed, the laboratory was used mainly for handling measurement equipment. Most high school teachers were not qualified for science teaching, especially in physics. It was not strange to find physicians lecturing on biology, and any successful student who had finished secondary school with good grades felt capable of teaching mathematics and physics.

During the 1950s the Ministry of Education tried to change the secondary school curriculum without much success. A lack of skilled teachers plus a great reluctance toward any innovation turned this attempt into failure. One change after another was made in the grading system, with no theoretical support.

Between 1960 and 1980 a conjunction of factors made some significant changes possible: 1) the emerging democracy after ten years of dictatorship; 2) the impact of the development of science curriculum which took place in the United States, the United Kingdom, and other countries over the two decades (PSSC, Nuffield, Harvard, etc.); 3) the decision of Latin American countries to join forces in modifying the structure and purposes of secondary school education; and 4) the influence of the behavioral sciences on curriculum design.

The effect of these factors upon science education in Venezuela can be summarized as follows:

1) Quantitative expansion of science education. Due to the continuous changes in the educational system, more young people who formerly studied in vocational schools entered the basic cycle of the secondary schools. The focus of this quantitative expansion was not just in terms of increasing the number of pupils in science courses but also in implementing a new curriculum on a national basis.

2) Diversification of opportunities for secondary science education. While the science curriculum for the elementary school is general in format, that for the basic cycle of the secondary school (biology, chemistry, and physics) is fully prescribed for all students. Science courses for the following diversified cycle have been designed to meet a variety of goals and interests.

3) Improvements in science teaching. Recognizing the fact that the ultimate success of implementing any new curriculum depends upon how well teachers are prepared for the task, efforts have been made to update teacher skills and knowledge. Of particular interest are the workshops and seminars, local and regional, offered by CENAMEC (National Center for Improvement of Science Teaching) and the Pedagogic Institute of Caracas. From 1975 to 1983 CENAMEC has offered 150 workshops for science teachers.

4) Improving the quality of teacher preparation. The last 15 years have witnessed an increase in the number of institutions for pre-service preparation of science teachers. The number of pedagogical institutes has increased from one to five, and many of the universities are offering science teaching degrees via their colleges or education. Currently, there are eight institutions where people can study to become science teachers.

Practices in pre-service preparation of high school science teachers have changed over the last two decades. During this period teacher education in the Pedagogic Institute of Caracas, for instance, has been changed from a three-year curriculum to a five-year curriculum. In 1969 a degree for secondary school teachers based on the Berkeley Physics Course was introduced, a new grading scale (evaluation) was established as well as academic guidance for each student (advising system). But above all, the major change was the possibility of multiple syllabi sequences, and multiplicity of outcomes for the graduating student in terms of different combinations; physics, physics and mathematics, mathematics and physics, etc.

In 1980, the new Education Law, whose implementation is at an experimental stage, changed the latest structure. The compulsory nine years of basic education and elementary school teacher training at university level are some of the innovations which undoubtedly will have a greater impact on science education in the near future.

A new integrated science curriculum has been developed for the basic education level; the one for grades 1-6 is in operation, while that for grades 7-9 is still in the process of adaptation.

In the diversified cycle (second level of the 1980 organization), nothing has been accomplished as yet. However, a project in a very preliminary stage in CENAMEC is aimed at developing a science curriculum for this level within the science, technology, and social frame of reference, without disregarding that it should: 1) give a conceptual support for further studies, and 2) provide skills for the non-college-bound student.

It must already be apparent that physics education in Venezuela is going through a slow, but constant, growth process. There are no less than eight third-level institutions in which some work in undergraduate physics education is continuing, or has recently taken place, including the Pedagogic Institute of Maturín, the Universidad Simón Bolívar, the Universidad Central de Venezuela, CENAMEC, the Pedagogic Institute of Barquisimeto, and others. The main areas of research and development seem to be taking place is:

1) Misconceptions in Undergraduate Physics Teaching
2) Project Work for Physics Teachers
3) Piagetian Stages and Tasks
4) Physics Curriculum
5) Personalized System of Instruction
6) Computers in Physics Teaching
7) Physics Laboratory and Equipment
8) Cognitive Processes.

The Pedagogic Institute of Maturín deserves particular mention since it has its own scholarly Review, and is active in at least three of the areas just quoted.

Another interesting effort in the improvement of physics education was the Latin American Conference in Physics held at the Universidad Simón Bolívar in 1974. In 1983 an International Seminar on Physics Education was held at the Institute of Advanced Studies (IDEA, Caracas). This seminar was attended by participants from ten countries and a group of physics education specialists; it was devoted to physics teaching at the secondary and university levels. Moreover, in 1986 the Institute of Advanced Studies (IDEA, Caracas) hosted an international event in which the emphasis was on the development of laboratory equipment for physics teaching. In December 1986 CENAMEC was host for another seminar in which the Venezuelan physics Curricula at all levels was analyzed.

Venezuelans consider that the undergraduate physics education in the universities has been successful, as can be seen from the number of graduates in the past few years (see Fig. 5).

In addition, the Pedagogic Institute of Caracas has graduated 512 physics and mathematics teachers (secondary school) between 1960-1972.

A figure of interest, for assessing the success of the undergraduate program in physics, seems to be the number of Venezuelan physicists who have obtained their MSc and/or PhDs in countries such as the United States, United Kingdom, France, Soviet Union, and Canada, among others. This statistic is difficult to ascertain because of the large number of sponsoring institution--governmental, private, and international. However, at least 75 Venezuelans have done successful graduate work, most of it abroad. The National Council for Science and Technology (CONICIT) alone sponsored 37 students since 1972 (14 in Venezuela).

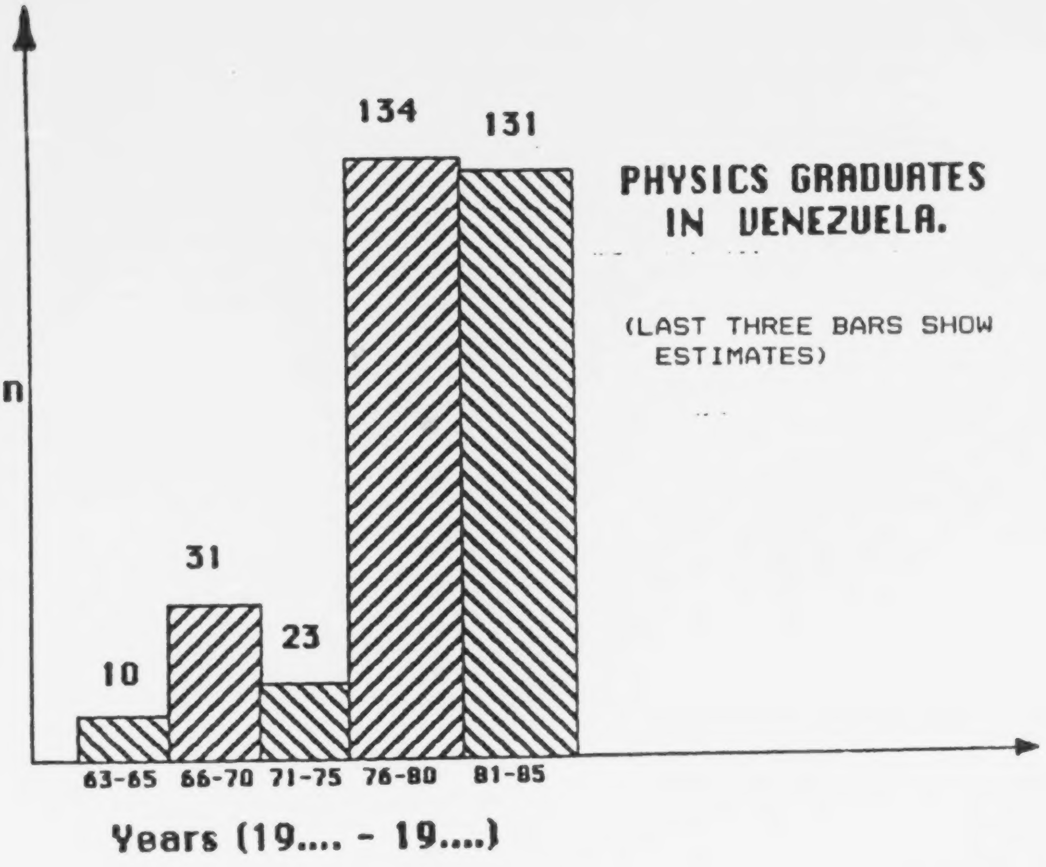


Fig. 5. Numbers of Venezuelan physics graduates, 1963-85.

The problems of undergraduate physics education are not to be concealed, however, There is ample evidence that a proper and correct view of physics is not usually offered to the students, particularly in introductory courses. The lack of simplifying physics situation, of physics intuition, and the like are the usual consequences of university lecturers who view their lecture courses as work not relevant to professional promotion. A major problem is the unending use of the same textbooks, year after year, for a given course. The introductory laboratory, with its classical "cookbook" style of work, the physics exams plagued with mere calculus or algebra but not with good physics, are also serious problems to be tackled. Evaluation, as it is in many countries, is one of the easily spotted problems.

Venezuelans are concerned about the decline in world oil prices which evidently affects their economy. Paradoxically, however, they feel that the economic crisis of the late 80s is forcing them to look within the country for solutions to their problems.

The Professional Physicist

While physics education has been improving in Venezuela during the past few years, the participation of physicists in industry is at best very limited or in its early stages. Their work is still in the traditional academic world. Teaching and limited research continues to be the basic dedication for physicists.

At present (1987), when many science educators are returning from abroad with advanced degrees (Masters and PhDs), there is a lack of jobs for physicists in academia. This situation is forcing many traditional departments to innovate their curricula and offer "hyphenated" degrees in fields such as biophysics, physical metallurgy, etc.

Many Venezuelans feel that the country has formed a "basic team of physicists" and the expansion of the curricula should be toward applied physics and industrial applications.

PHYSICS EDUCATION IN THE WESTERN HEMISPHERE; A CROSS-COUNTRY SUMMARY

Introduction

In this cross-country summary, an attempt will be made to analyze similarities and differences found on the state of physics education in the Americas. Also, editorial comments will be included relating to the different approaches used to improve teaching and learning in physics in different countries.

Moreover, through this closing chapter, some remarks will be included on undergraduate and graduate programs in physics and the impact of modern technology on physics education.

Thus, no editorial recommendations or solutions will be proposed because improvement of physics education, in general, is not an isolated problem that could be excluded from other political, economic, or cultural factors. It is the responsibility of each country to seek the solutions to improve physics education appropriate to their particular situation.

Highlights

There are five important factors that impact the state of physics education in the Americas:

1. The level of commitment of the higher authorities in all the countries (ministries or Secretaries of Education, Supervisors, Regional Directors, etc.) to support rigorous and high quality programs in physics instruction.
2. Inadequate communication and cooperation among organizations (national and international), individuals, and educational institutions.
3. The political, economic, and social situation of each country.
4. The physical location of the educational institutions and demographic character of the student body.
5. The preparation and attitude of teachers (primary and secondary level) and faculty (tertiary) responsible for the teaching of physics.

These factors combine or reinforce with each other to affect the character and/or programs in the sciences and particularly in physics education at all levels.

In the analysis of all the countries, it can be found that the level of commitment of the government and/or administrators is perhaps one of the most important factors in the educational system of a country, especially at primary and secondary level. In addition, the economic situation and funds available for education are also important factors, but it is also true that the need for better communication among educators in all the countries and even within a particular nation will help to stimulate exchanges of ideas and to make better use of human resources and knowledge.

Moreover, in most of the countries of the Western Hemisphere, perhaps with the exception of the United States (and only at the university level), the differences among schools, colleges, and universities in urban areas compared to those existing in rural areas is remarkable.

Many physics educators complain about rules and regulations imposed on them by the higher authorities in their countries. They also indicate that poor working conditions, including low salaries, particularly at primary and secondary levels, result in poor performance by the teacher and low self-esteem.

In addition, it can be found through this report that the activities of physicists are mainly academic. Their participation in industry is at best very limited in most of the countries in the Americas.

Physics Education at the Primary School Level

Students enrolled in this level of education in the majority of the countries in the Western Hemisphere do not receive any specific instruction in physics. In some countries, physics topics are included in courses in general science which are like a mosaic dealing with biology, chemistry, physics, and sometimes with environmental studies. This situation can be observed even in highly industrialized countries such as the United States of America and Canada. One of the major problems mentioned by well-informed observers is the basic preparation and poor training of the primary school teacher in the sciences.

In many countries, teachers for this level are not prepared in the universities. They receive their education in institutions that are modified versions of the secondary school level. The preparation that they receive in the sciences might be even lower than that attained by a student who follows a regular secondary school program for admission to the university level. In other countries the pedagogical contents are emphasized in the preparation of teachers while the subject matter or knowledge of content is left out.

Teachers, particularly at the primary school level, should have expertise in the contents they teach but, at the same time, the importance of pedagogical understanding of what makes the learning of specific topics difficult or easy should be included in their preparation. It is a complex problem, but one that must be faced by institutions and/or schools dedicated to educating primary school teachers. The basic concepts of physics should be included at an early stage in the education of children. Primary school teachers must be prepared in this area.

There are many factors involved in this problem. In developing nations the rapid population growth creates the need for more primary school teachers and at a faster rate. The economies of many countries do not grow to properly increase the number of institutions and/or to provide incentives for students to prepare for a primary school teacher career. The remuneration for teachers is very low compared to graduates in other careers. Sometimes the educational policies are affected by political changes and educators have very little input in the process.

The efficiency of the primary school level is very poor in many nations and the dropout rate is high, particularly in the rural areas. There are continuous efforts being made to improve this situation, including some interesting modifications that are being introduced in many nations. The decentralization of the educational system observed in some countries has helped to improve this situation, but in some cases it has created more bureaucracy resulting in little change in the system.

The majority of the teachers at this level, according to the data available, are females with very low salaries. The primary school teacher is, in general, rated very low compared to other professionals such as engineers, physicians, university faculty members, etc.

Many nations are trying different types of approaches in the primary school level, including division into two cycles. The first cycle is being served by a school teacher who takes care of all the disciplines. In the second cycle, teachers are selected according to their specialties. In other countries, the reports do not indicate major improvements due to the lack of preparation of the teachers, mostly in the physical sciences.

As noted earlier, when the data available at present is compared with that of 30 years ago, some major improvements have been attained. However, physics education in the primary school level of most education systems is, at best, in the early stages of improvement.

Physics Education at the Secondary School Level

An analysis of the state of physics education at the secondary level indicates that during the past 30 years or so there have been general improvements in the physics course contents, the level of sophistication of these courses, and in the teacher's preparation. These improvements, however, are not as dramatic as those that have taken place at the unviersity level.

The similarities and differences found in the state of physics education among the different nations are related to the factors noted earlier in this chapter. The levels of commitment of the higher authorities in each country to the improvement of physics education have resulted in positive as well as negative changes.

In many countries the decisions regarding policies which involve the number of physics courses required for graduation in the secondary or pre-university level reside in the hands of administrators with very little knowledge about the subject matter, the importance of science in the curricula, and the needs for pedagogical preparation of teachers. Even in countries where decentralization of the educational system has been established such as the United States of America, Canada, Costa Rica and, most recently Guatemala, Chile, etc., educational policies have not been very favorable for the improvement of science.

Communication among individuals and organization in the different countries or even in a particular country with small size and population has resulted in an extraordinary delay in the exchange of ideas and/or modernization of courses.

In most countries of the Western Hemisphere, the physical location of the schools and the demographic composition of the student body have not been taken into account in the requirements of courses and curriculum in general. As a result, there are enormous differences among rural and urban schools. The level of instruction has been affected by differences between private and public institutions, particularly in countries where the economic support for public schools is minimum. Even in highly industrialized countries, it is possible to notice differences among schools in suburban areas and inner-city schools.

Moreover, the preparation of the high school teacher is inadequate in most of the countries in the Western Hemisphere. The high school teacher in physics is normally educated in the universities, and even with new rules requiring the appropriate degree and credentials, it is possible to find high school graduates, university students, and professionals in engineering, pharmacy, etc. teaching physics at the high school level. There are many exceptions, but still many physics teachers lack basic knowledge of physics, pedagogical methods to teach the discipline, or are not aware of the variety of instructional materials available for physics instruction. This phenomena can be observed even in highly developed countries.

In the developing countries of the Western Hemisphere, physics teachers at the secondary level sometimes work in more than one institution (part-time) to be able to obtain a decent salary. In other countries, the number of physics teachers without minimum qualifications or even an appropriate degree is very high. In countries where teachers are required to be in possession of the appropriate degree, many of them are poorly trained to teach physics. It is really interesting to n otice that, while in many countries physics as a subject is mandatory, in others it is an elective subject and only a small proportion of the graduates have received any instruction in physics prior to graduation. The United States, for instance, which is one of the countries in the world with the highest percentage of students completing their secondary education, fares poorly in terms of the percentage of students who have received any instruction in physics. A recent survey of high school physics in the United States indicates that only about 17% of all high school students are receiving instruction in physics.

The problem of the course contents in secondary school physics must be mentioned. Many of the courses are extremely traditional and in many countries the laboratory component is practically nonexistent. Inadequate physical facilities, lack of equipment, and poorly trained personnel aggravate the situation.

There is very little balance between the "content aspects of teaching and the elements of the teaching process."

According to the reports prepared on each country, there are major and serious efforts in many of the countries in the Americas undertaken by organizations and groups of individuals to improve physics education across the Americas.

Teacher-training programs, summer institutes, joint efforts established by two or more countries, etc. indicate that these problems are finally being faced by many countries, but still there is a lot of ground to be covered.

Physics Education at the Tertiary Level

The analysis of the state of physics education at the post-secondary level in the Americas shows major improvements during the past 30 years.

In many countries there have been certain periods where no major accomplishments can be noticed. In some cases these periods were influenced by inflationary periods or changes in the economic situation. In some regions of the continent, political problems and changes have impacted the educational system including the tertiary level. The general situation in physics, however, looks promising even though many obstacles must be overcome.

During the 50s and early 60s only the United States and Canada were able to show solid educational programs in physics both at the undergraduate and graduate levels. Other countries such as Argentina, Brazil, and Mexico, however, were able to make major advances in physics education and research in physics.

At present, there are several new institutions of higher education through the Americas with new programs, better-qualified faculty, and slow but steady change and modernization.

In most of the unviersities the physics faculty has been grouped in departments and/or schools of physics, and while the major responsibility is still teaching and offering service courses for students in the sciences, engineering, medicine, etc., excellent undergraduate and some graduate programs can be found in these institutions. Doctoral programs in some institutions of higher education in the developing countries are comparable, in many cases, to those offered by European, Canadian, and U.S. institutions.

Venezuela, perhaps, is one of the countries with the most dramatic changes in physics education at the undergraduate level during the past few years.

Undergraduate physics programs are being developed in many institutions based on the particular needs of the country. It is true, however, that some of these programs are very rigid, particularly at the undergraduate level. In some countries, it requires five years to complete the first undergraduate degree, compared to four years in other institutions. This rigidity apparently was necessary to provide institutions of higher education with well-prepared young faculty at a faster rate. In most cases the young graduates go abroad to obtain their graduate degrees.

Faculty members with PhD degrees in physics have noticeable increased during the past few years. Unfortunately economic pressures and political problems have forced many of them to emmigrate. Still, the ranks of PhDs are increasing.

The problems of undergraduate education through the Western Hemisphere cannot be concealed, and changes, particularly in introductory physics courses, are necessary. These problems are present even in the highly industrialized nations. In the United States, for instance, a commission is seriously seeking solutions and/or recommendations for improving introductory physics courses.

One of the major obstacles throughout the Western Hemisphere is the situation of laboratory instruction including needs for upgrading available equipment and, in general, to improve physical facilities for experimental work.

Scientists in many countries are virtually isolated from their colleagues, and communication with their peers in other countries is inadequate. This situation is more prevalent among the countries in Central and South America where efforts are needed in several directions. For instance, it is necessary to improve governmental support for physics education at all levels, including better facilities, higher salaries, and more freedom of action by scientists. In addition, the participation of the private sector, including industry, should be encouraged.

Thus, while changes in physics education are evident throughout the Western Hemisphere, individuals, organizations, and educational institutions should continue seeking solutions for problems still present and look forward to the challenging 21st century.

The Professional Physicist

Many of the highly industrialized nations in the world have relied on their scientists and engineers for economic growth and international competitiveness. Physicists have made major contributions toward solutions of problems confronted by modern technology. In the Americas, however, the majority of the physics graduates are still found in academia, mainly teaching. The exception to the rule is the United States of America where a large proportion of physicists are employed by industry, research institutes, and national laboratories.

However, since the 60s, there has been a trend in many nations in the Americas to open research institutes--institutes of physics attached to, but in some cases independent from--the faculties of sciences in the universities. The trend has also been to establish semi-autonomous organizations and to promote internationally sponsored groups which have increased the participation of physicists in research in pure and applied physics.

The appearance of these groups and/or organizations, many of them sponsored by the governments, and the establishment of graduate programs in many universities have had some impact in opening new horizons for the professional physicist. Still the participation of the professional physicist outside the academic world is very limited.

Developing countries can no longer exclusively rely on external sources for technological development. They should take a more active part in improving their own development even if they use foreign investment and some import of technology.

Some countries perhaps might establish policies which could include appropriation of national budgets for research and development. Unfortunately very little attention has been given to the participation of the professional physicists in research and development.

Private industries and industries which are part of international conglomerates have overlook the importance of physicists cooperating with the private sector. Government, universities, and professional organizations should take a more aggressive position on this issue in the countries of the Western Hemisphere.

Final Remarks

The comments on this cross-country summary represent to opinion of the Editor in Chief and should not be taken as a position of the Council of Interamerican Conferences in Physics or the American Association of Physics Teachers. The Editor will welcome comments by individuals, organizations, and government officials across the Americas that will help to update future versions of this report.

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